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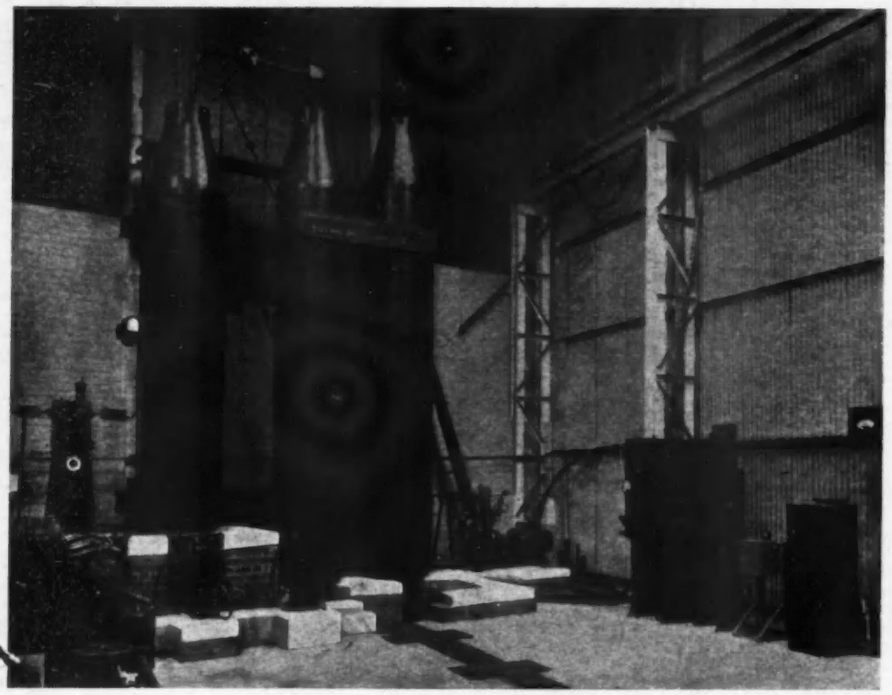

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JULY 4, 1941. VOL. 152.

ENGINEERING.

THE CONTROL OF POWER IN LARGE INTER-CONNECTED ELECTRIC SUPPLY SYSTEMS.

By T. F. WALL, D.Sc.

THE SPACE CHARGE.

§1. *Significance of the Space-Charge in Heavy Current Work.*—By the year 1897, J. J. Thomson had shown that electrons were emitted from a metal which was heated in a vacuum, and also when a beam of ultra-violet light was directed on to the cold surface of a metal in a vacuum. Although these facts attracted immediate and universal scientific attention, it was only a few years before the last war that the practical importance and possibilities of the "free electron" began to be realised. Until then, few people thought of electricity—apart from lightning—except as being confined in material bodies and it is true that the essential practical applications of electricity for heating, lighting, and power are realised when the electrons are so confined.

Although technical interest in free electron currents has so far been confined mainly to appliances which comprise highly evacuated containing vessels, the intensive study of the complicated phenomena involved in the efficient, reliable, and durable performance of these applicances has provided valuable information for the elucidation of the mechanism of high-power electric arcs formed in oil, air, or hydrogen, and has led directly to the development of circuit-breakers which are capable of controlling very large amounts of energy under a severity of conditions which, a few years ago, would have been considered to be fantastically impossible. An intelligent study and appreciation of recent developments in this domain is only possible when the fundamental phenomena of arc-discharge are kept in mind.

Fig. 1.

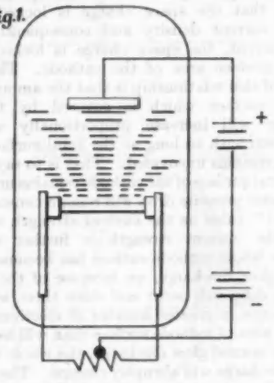


Fig. 2.

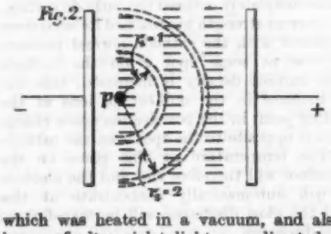


Fig. 3.

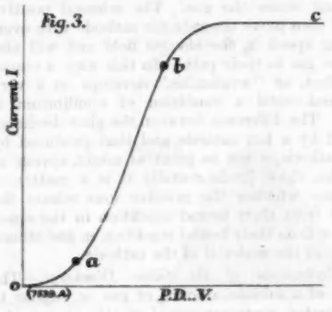


Fig. 4.

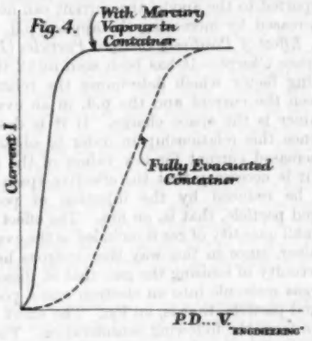


Fig. 5.

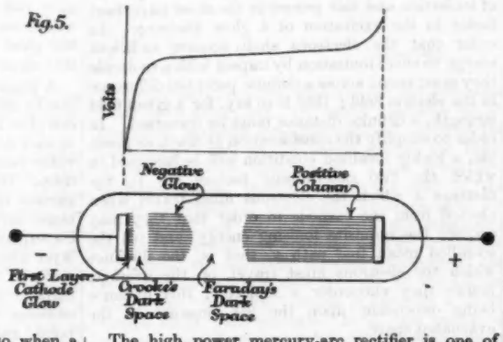
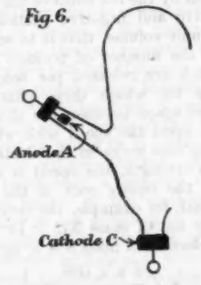


Fig. 6.



The high power mercury-arc rectifier is one of the most notable of the remarkable flood of electrical engineering achievements which have taken place during the last two decades and provides a striking example of the far-reaching applications of the fundamental principles of electrical engineering as applied to both light-current and heavy-current technique. Such vacuum rectifiers are to be classified as switchgear, the switch mechanism consisting of a movable stream of electrons, that is an electric arc, in an evacuated space. The unity of all branches of electrical engineering in their countless ramifications is gradually becoming more generally realised and the distinction between light- and heavy-current work is seen to be a purely arbitrary one. Actually, there is no such fundamental distinction and the difference is generally merely a question of the relative importance of the electromagnetic and electrostatic quantities as dependent on the frequency of operation. A striking example of this unity of the fundamental principles is found in the application of the theory of high-tension long-distance transmission lines to the solution of the problems of radio filter circuits.

The well-known laws which define the flow of currents in metal conductors entirely fail when currents which are formed of free electrons, or ions, are considered. For a metal conductor, the potential is related to the current by Ohm's law, whereas with electronic currents in open space the controlling factor is the so-called "space charge," and in place of the inexhaustible store of electrons which is available in a metal conductor, for currents formed by electrons in open space it is first of all necessary to provide the electrified particles of which the electronic and ionic currents are composed.

§2. *The Meaning of Space Charge.*—Suppose two electrodes, as in Fig. 1, on page 1, are, respectively maintained at positive and negative potentials and that the space surrounding them is completely exhausted of gas. If the temperature of the negative electrode, that is, the cathode, is raised to a sufficient degree, electrons will be ejected and will travel towards the anode under the influence of the electrostatic field between the electrodes. This movement will form an electronic current. At first sight, it might be supposed that all the electrons which are ejected from the cathode would reach the anode when only a small p.d. was applied between the electrodes; that is, that the current strength would be very little affected by the p.d. Actually,

however, the fact is quite otherwise. At any point, such as p in Fig. 2, an electron will be under the control, not only of the field due to the charges on the electrodes but also of the field due to all the other free electrons in the space between the electrodes, that is to say, the field due to the space charge. Thus, for example, the free electrons which are embraced by the two spherical shell elements shown, of which the radii are, respectively, $r_1 = 1$ and $r_2 = 2$, will exert the same force on the electron at p in accordance with Coulomb's law of inverse squares.

The question then arises as to how the current value I will be related to the p.d. V between the electrodes. For small values of V the space charge will drive most of the electrons back to the cathode, so that the rate of increase of current will be small, as is shown by the portion O a of the graph, Fig. 3. When the pressure V increases the force exerted on the electrons by the field due to the electrodes will increase and at the same time, the controlling effect of the space charge will diminish owing to the increased speed of transport of the electrons across the space. By direct calculation it can be shown that the rise of current with pressure will then be defined by the equation,

$$I = k V^{\frac{3}{2}}$$

where k is a constant. The approximate range for which this expression holds is shown by $a\ b$ in Fig. 3. When the p.d. between the electrodes is still further increased the rate of increase of the current diminishes and eventually reaches a saturation value as is shown by the portion $b\ c$ of the graph, Fig. 3. That is to say, as soon as all the electrons which are ejected by the cathode in unit time are actually transported to the anode, the current can no longer be increased by increasing the applied p.d. V.

§3. *Effect of Positively Charged Particles (Ions) on the Space Charge.*—It has been seen in §2 that the deciding factor which determines the relationship between the current and the p.d. in an evacuated container is the space charge. If it is desired to influence this relationship in order to obtain, say, an increased current for low values of the applied p.d., it is necessary that the effective space charge shall be reduced by the injection of positively charged particle, that is, an ion. The effect of this if a small quantity of gas is included in the evacuated container, since in this way the electrons have the opportunity of ionising the gas, that is, dissociating each gas molecule into an electron and a positively charged particle, that is, an ion. The effect of this is seen from the following consideration. The space charge is given by the net effect of the total number of free positive and negative particles which are released per unit volume, that is to say, it depends not only on the number of positive and negative particles which are released per second, but also on the time for which these charged particles remain in the space between the electrodes or, in other words, upon the speed with which the electrons and the ions move in the electric field. For a given field strength, the speed is inversely proportional to the square root of the mass of the particle, so that, for example, the ratio of the speed of a mercury ion of mass 332×10^{-24} gm. to the speed of an electron of mass $9{\cdot}8 \times 10^{-28}$ gm. will be

$$\sqrt{\frac{9{\cdot}8 \times 10^{24}}{332 \times 10^{23}}} = \frac{1}{615}.$$

That is to say, a mercury ion will move at a speed only about $\frac{1}{615}$-th that of an electron. This fact explains the astonishingly large effect on the current-pressure characteristic. Fig. 4, page 1, when a minute amount of gas or vapour is admitted to the evacuated space between the electrodes. Thus, if only sufficient mercury vapour is admitted so that $\frac{1}{615}$-th part of the total current is accounted for by the movement of the positive particles (ions), the space charge will become zero since the mercury ions will remain 600 times as long on their journey in the space between the electrodes.

The reduction of the space charge by means of positive ions is of the greatest practical importance, since the requisite p.d. for a given current will be reduced as the magnitude of the counteracting space charge is reduced and this implies a corresponding reduction of the power loss in the appliance. That is, there will be a corresponding reduction of the cooling necessary to dissipate the heating loss. Reducing the magnitude of the space charge in this way makes it possible to construct containing vessels with gas or vapour filling which can be used for heavy currents. The use of highly evacuated containers must be confined to light current operation on account of the difficulty of dissipating the heat when heavy currents flow in such gas-free containers.

§4. *The Glow Discharge.*—The simplest type of glow-discharge is that in which electrons are discharged from the cathode by raising its temperature, as has been considered already in §2 and §3. These electrons are accelerated in the electric field and, by ionisation of the gas, produce positive ions. The ions then travel towards the cathode, neutralising the negative space charge on the way and so release those electrons in the neighbourhood of the cathode which were bound by the space charge, a state of equilibrium being eventually attained which is dependent on the magnitude of the p.d. between the electrodes.

There is another type of glow discharge which is of great practical significance and which does not depend upon a heated cathode for the production of the electrons. This employs a cold cathode, which actually produces a glow discharge very similar to that which is obtained from a hot cathode. This may be explained by means of the following considerations. In a highly evacuated containing vessel there will always be individual free electrons present which may be due, for example, to radio-active effects from which no such space will ever be entirely free. Such free electrons will become accelerated in the electric field between the electrodes and ionise the gas. The released positive ions will then move towards the cathode with ever-increasing speed in the electric field and will also ionise the gas in their path. In this way, a cumulative effect, or "avalanche," develops at a very high speed until a condition of equilibrium is reached. The difference between the glow discharge produced by a hot cathode and that produced by a cold cathode is not so great as might appear at first sight, since fundamentally it is a matter of indifference whether the positive ions release the electrons from their bound condition in the space charge, or from their bound condition in the atomic structure of the material of the cathode.

§5. *Mechanism of the Glow Discharge.*—The addition of a minute amount of gas or vapour to the evacuated container vessel greatly complicates the process by which a glow-discharge is produced. The electrified carriers (electrons and ions) newly released by ionisation, partake in the further process of ionisation and this process is the most important factor in the excitation of a glow discharge. In order that the electrons shall acquire sufficient energy to effect ionisation by impact with a molecule they must travel across a definite potential difference in the electric field; that is to say, for a given field strength, a definite distance must be traversed. In order to simplify the consideration as much as possible, a highly idealised condition will be assumed in which the two determining factors are (i) the distance x which the electrons must travel when ejected from the cathode in order that they may acquire the requisite ionising energy, and (ii) the so-called mean free path y, that is, the distance which the electrons must travel, on the average, before they encounter a molecule, this distance being dependent upon the gas pressure in the evacuated space.

Assuming that at the commencement of the process the potential distribution is more or less uniform and that x is considerably greater than y, for example, $x = 2y$, so that only those electrons will be able to produce ionisation which have been able to travel the distance x before impact with a molecule. Due to this impact, however, a positive space charge will be formed at the distance x from the cathode, and the potential at this point will be raised relatively to the cathode. This implies an increase in the strength of the field in this neighbourhood and a consequent reduction of the distance x, which an electron has to travel in order to acquire the requisite ionisation energy. A little consideration will show that the general effect of this process will be that the centre of generation of positive ions will gradually draw nearer to the cathode until eventually the critical condition will be reached for which $x = y$. At this distance from the cathode a strong positive space charge will be developed, since at this place the electrons will most frequently collide with the molecules with adequate energy. Further, the released ions will have their minimum speed at this space and will, in consequence, linger in this region for the maximum time. A large p.d. will thus be developed between this region and the cathode; in most cases, this p.d. forms the main portion of the total p.d. between the anode and the cathode. This p.d. is known as the cathode drop and both theoretically and technically is the most important potential factor in the formation of any glow discharge. This region can be seen as a dark space (Crookes' Dark Space) and is bounded by the cathode glow on one side and the negative glow on the other, as is shown in Fig. 5, on page 1.

By means of considerations which involve not only ionisation phenomena but also the losses at the walls of the containing vessel and the impact of the electrons on the anode, it is possible to account for the other main discharge formations of Fig. 5, such as the "positive column" and the "anode drop." The fundamental consideration which controls these phenomena is that a condition of equilibrium must be established between the various operating factors in the complicated sequence of processes.

§6. *Transition from Glow Discharge to Arc Discharge.*—As already pointed out, a complete statement of the conditions of equilibrium would involve highly complicated relationships but it may be said that the space charge is locked with a definite current density and consequently, for a given current, the space charge is locked with a definite surface area of the cathode. The consequence of this relationship is that the amount of the cathode surface which is covered by the glow discharge will increase proportionally with the current strength so long as the total surface of the cathode remains uncovered. That is to say, so long as the total surface of the cathode remains uncovered, the cathode pressure drop will remain constant at its "normal" value as the current strength is varied. When the current strength is further increased after the whole cathode surface has become covered by the glow discharge, an increase of the cathode pressure drop will occur and since there will be, in consequence, a greater number of electrons ejected per unit area of cathode surface than will be the case with the normal glow discharge, the whole character of the discharge will abruptly change. The negative glow will contract to a single brilliant spot which will move restlessly over the cathode surface; thus the glow discharge will have become transformed into an arc discharge.

A general idea of the physical sequence of events can be obtained as follows· Suppose that the cathode glow has completely covered the cathode surface, or that the current strength has reached its maximum value consistent with the cathode normal pressure drop. If now at some spot x on the cathode surface the current density is increased, this will cause an increase in the number of ions at the corresponding point in the positive ion space charge layer which is opposite to the spot x on the cathode surface. The temperature at this place on the cathode surface will therefore rise and the electron emission will automatically concentrate at this point, and the glow discharge will be transformed into an arc-discharge.

§7. *Technical Significance of Electronic and Ionic Currents.*—The technically important appliances which utilise electronic and ionic currents may be considered as being of two types, namely, those which operate as rectifiers, and those which operate as relay control appliances. The rectification characteristic is obtained by using electrodes which are of so different a nature that one acts exclusively as the cathode and the other exclusively as the anode, so that the current can only flow in one direction. In the case of those electron appliances which operate with a separately-heated electrode, this feature ensures that the hot electrode functions exclusively as the cathode from which the electrons are ejected due to the high temperature. This class of appliances includes the hot-cathode high-vacuum

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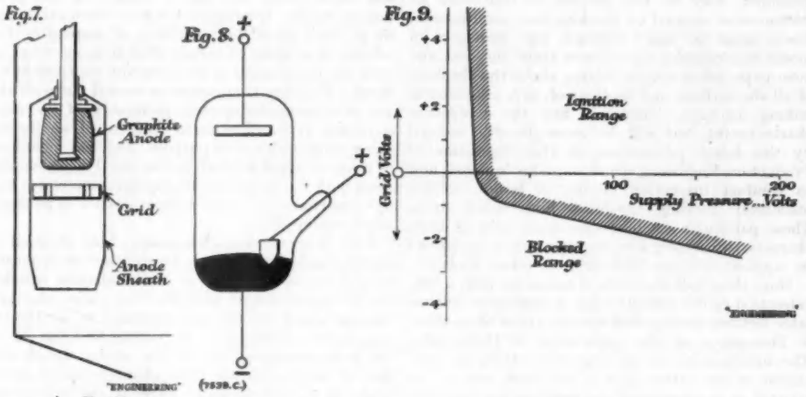
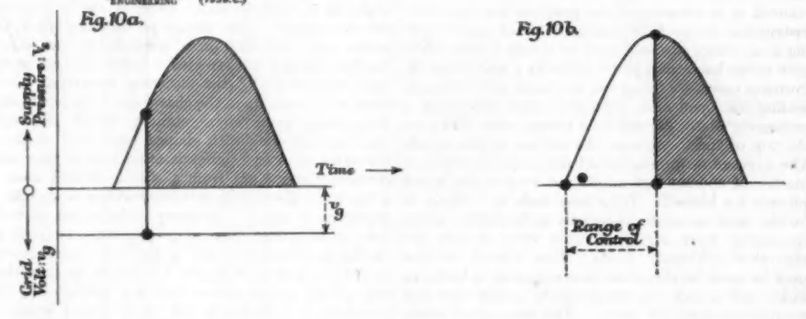
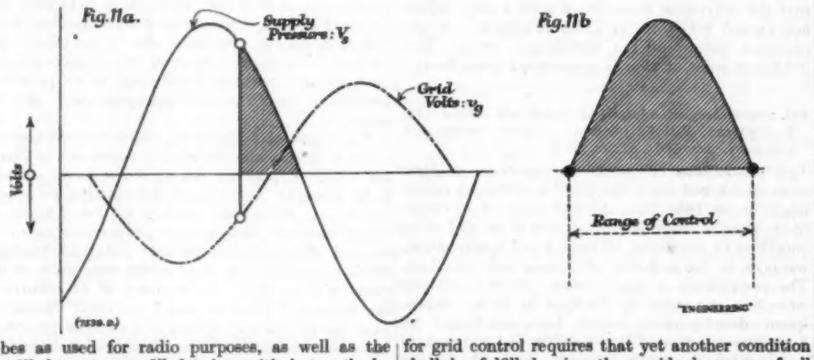






tubes as used for radio purposes, as well as the gas-filled or vapour-filled tubes with hot cathode, known by the name Thyratron.

With electrodes of different degrees of vaporisation and no separate heating for the cathode, that electrode which vaporises the more readily becomes the cathode; this is particularly the case when the operation is by means of an arc discharge. This class of appliance comprises the mercury-arc rectifier with mercury cathode and graphite anode. The control or relay action of electronic appliances is obtained by means of a third electrode, which is termed the grid. The control property of such an electrode depends upon the fact that the potential to which it is charged gives it the characteristic of a space charge of adjustable magnitude and sign. In the case of the hot-cathode vacuum tube the conditions for this type of control operation are easily fulfilled. Such appliances are used as valve amplifiers and for many kinds of light-current control operations. Much more complicated is the mechanism of operation of appliances which contain gas or vapour filling, such as the mercury-arc rectifiers of heavy-current practice. In this case, the charge on a grid, which is at negative potential with respect to the cathode, is neutralised by the space charge of the positive ions which travel towards the grid, so that this grid control cannot exert any influence on the operation of an arc discharge which is already established.

The successful functioning of rectifying appliances for grid control requires that yet another condition shall be fulfilled, viz., the rapid clearance of all electrified particles from the enclosed space of the containing vessel or, in other words, the rapid de-ionisation of this space. Those electrified particles which, shortly before the end of the active half-cycle of the supply pressure have not been neutralised by contact with the containing walls of the vessel may cause the path to be conducting during the normally inactive half-cycle of the supply pressure; this may give rise to the highly-dangerous "back-fire" which is actually a short-circuit effect. On the other hand, the residue of unneutralised electric particles may produce a space charge which will surround the grid and so influence, or even neutralise, its control property, it being observed that the grid must acquire its operating positive charge shortly before the commencement of the active half-cycle (see also §9).

§8. *Electronic Appliances for Heavy-Current Operation.*—For heavy-current operation two main types of appliance are used, viz., (A) The Hot-Cathode type, and (B) the Mercury-Arc rectifier type.

A. The Hot-Cathode Type.—In this type the cathode is coated with an oxide which readily emits electrons at a relatively low temperature, while the presence of a small amount of gas or mercury vapour supplies the positive ions. It has already been shown in §3 that these ions, notwithstanding their relatively insignificant contribution to the strength of the current flow, are able to exert a powerful control on the pressure drop (see Fig. 4), on account of their neutralising effect on the negative space charge. The cathode pressure drop in this type of appliance is normally greater than the ionisation pressure of the gas filling and, in the case of mercury vapour, the drop will be not less than 12 volts. The current strength must not be increased beyond the value which corresponds to the number of electrons which are produced per second, since, otherwise, the positive ions will have to generate the requisite excess of electrons by bombardment of the hot cathode; this will give rise to an increase in the pressure drop and a consequent destruction of the cathode. This type of heavy-current rectifier is seldom used for currents of a greater strength than about 100 amperes.

B. The Mercury Vapour Type.—In place of the electron discharge from a hot cathode, this type makes use of a mercury vapour arc. The easily vaporised mercury which is produced by the high temperature of the hot spot which is formed by the contraction of the glow discharge, as already described in §6, produces a copious supply of electrons and ions. The ignition of the arc is, in general, obtained by means of a continuously burning auxiliary arc, which is automatically produced when the appliance is switched on to the supply mains. A special ignition electrode is provided for the purpose, which dips into the mercury pool when the main supply is switched off and is withdrawn from the mercury pool by means of a solenoid immediately the supply is switched on. The cathode pressure drop in this type also must not be greater than about 12 volts. While, however, in the case of the hot-cathode type the container vessel is usually of spherical form into which the electrodes project, in the mercury-arc type the anodes must be arranged either in extension arms, as is the case when glass bulb vessels are used (Fig. 6, on page 1) or each anode must be provided with a hood or sheath of which the cross-section is small relatively to the current strength. The consequence is that this type involves a relatively longer "positive column" (see Fig. 7) than is the case with the hot-cathode type. In addition to the cathode drop of 12 volts, there is the drop in the positive column as well as the anode drop, so that in this case a total pressure drop of from 20 volts to 30 volts is obtained.

§9. *Grid Control of Heavy-Current Rectifiers.*—The most important type of control is the regulation of the mean strength of current in the container vessel itself without the use of any series impedance. This method of control is the outstanding advantageous feature of the heavy-current rectifier, since it does not involve any loss of energy. The practical methods for the application of this grid control may be grouped under two headings, A and B, according as the half-cycle under consideration would remain without current or would be in active operation.

A. Half-Cycle without Current.—This case only concerns rectifiers with a mercury cathode. The characteristic feature of the method is that the supply pressure is not sufficient to ignite the arc, but is adequate to maintain it when burning. Ignition is effected by means of an auxiliary spark and the control consists in choosing the moment at which ignition is obtained. The mean strength of the currnet will then be large, medium, or small, according to whether the moment of ignition occurs at the beginning, near the middle, or towards the end of the half-cycle concerned. The modern form of this appliance is the Ignitron, in which ignition is obtained by applying a relatively small pressure to a rod of semi-conducting material which projects into the mercury pool, as shown in Fig. 8, page 3. At the boundary between this semi-conductor and the mercury, a relatively high field strength will be developed and in consequence, a glow discharge will be produced which will ignite the rectifier. As in other similar processes, the exact moment of ignition cannot be fixed with any great precision and the appliance is consequently only suitable for relatively rough operations. In America and on the Continent this type of grid control is widely used for electric welding processes and from the points of view of robustness and simplicity it has great advantages.

B. Half-Cycle in Active Operation.—This type of

control is applicable to either the hot-cathode type of mercury rectifier or the mercury-arc type having a continuously burning auxiliary electrode. The characteristic feature of the method is that in either case, the arc would be burning throughout the complete half-cycle under consideration if the grid control were absent; that is, the grid control determines the precise moment in the half-cycle at which ignition is allowed to take place. By giving the grid a suitably large negative charge, ignition is prevented and by suitably reducing the magnitude of this charge ignition is effected. A complete survey of this principle is most easily obtained by means of the ignition characteristic which is shown in Fig. 9, page 3. For each value of the supply pressure applied to the rectifier there is a definite value for the negative potential of the grid above which the discharge is blocked and below which ignition will occur. This limiting value of the grid potential is termed the ignition pressure. An outstanding feature of this principle of control is that it provides an extremely exact ignition mechanism by means of which the moment of ignition can be determined with a high degree of precision and with no energy loss.

One method of applying this principle is illustrated in Fig. 10*a*, page 3. If a negative potential of definite constant value is applied to the grid, ignition will take place at that moment at which the supply pressure reaches the magnitude that corresponds to the given grid pressure and is defined by the ignition characteristic of Fig. 9. A little consideration will show that the limitation of this method is that it is only applicable to the ascending portion of the supply pressure half-cycle, so that regulation is only possible over the range from 0 deg. to 90 deg. in Fig. 10*a*. The active portion of the half-wave is shown shaded in Figs. 10*a* and 10*b*. In order to obtain control of the ignition throughout the complete half-cycle, the device known as the Toulon control may be used. In this method, the phase of the grid pressure relatively to the anode supply pressure is adjusted so that, for each value of the phase displacement from 0 deg. to 180 deg., there is a definite and distinct moment of ignition. The principle of operation of this device will be apparent from an inspection of Fig. 11*a*, the control being available for the full half-cycle, that is, from 0 deg. to 180 deg., as is shown in Fig. 11*b*. It is to be observed that the precision with which this type of grid control can be operated is dependent upon the grid being completely charged to the requisite potential before the half-cycle under control actually commences, as has been pointed out already in §7.

(To be continued.)

LITERATURE.

Accuracy in Machine Tools: How to Measure and Maintain it. By DR. GEO. SCHLESINGER. Edited by D. F. GALLOWAY, Wh.Sc., B.Sc. London: The Institution of Production Engineers. [Price 3*s.* net.]

A PROPERLY organised repair department of a machine shop is required not only to deal with breakdowns and to keep the machines running, but also to maintain them so that accurate workpieces are produced. To take a simple case; if the longitudinal traverse of the cross slide on a turret lathe is not strictly parallel to the corresponding travel of the turret it will be possible, with some types of set-up, to produce hollow cylindrical parts, which should be uniform throughout, with a varying wall thickness. In practice, mathematical parallelism is not obtainable and a tolerance must be permitted. What this should be for various classes of machine is laid down in *Acceptance Test Charts for Machine Tools* which was published jointly by The Institution of Mechanical Engineers and The Institution of Production Engineers last year. Although these charts have not been adopted by makers generally as a basis on which machine tools should be accepted by a purchaser, they none the less, embody the essentials of good practice and certainly form a reliable basis by which a repair and maintenance department can direct its activities.

The purpose of the acceptance charts is to lay down standard tolerances for the various types of tool and, although they incidentally convey information indicating how those tolerances should be measured, they do not purport to constitute an instructional manual on machine tool maintenance. There must be many foremen and managers of repair departments who do not know the best and most expeditious way of setting about the checking of all the surfaces and motions of, say, a horizontal milling machine. They will find the acceptance charts useful, but will be more directly assisted by this latest publication of The Institution of Production Engineers, which explains in detail how to conduct inspection checks of lathes, milling machines, grinding machines and radial drills. These particular machines are dealt with as main characteristic types, but the information given can be applied without difficulty to other tools.

More than half the book is taken up with a consideration of the general rules of inspection and the later section, dealing with specific types of machine, is illustrative of the application of these rules. The information on erecting and setting-up, contained in the earlier part of the book, may be instanced as an example of the practical nature of the instruction given. It is pointed out that when erecting a machine, surfaces may be checked with reference to the horizontal plane either by a spirit level or, in many cases, by filling the vee ways with a liquid, sealing the open ends with clay, and traversing a measuring point, carried by a bridge piece riding on the top of the ways, over the surface of the liquid. The average shop man would use a spirit level as a matter of course, but might not evolve the liquid process for himself. With long beds it is likely to be the more accurate, especially as workshop levels frequently have errors of their own outside the allowable tolerance limits. This liquid method may be used to check the movement of a table, or slide, over a bed; or alternatively a taut wire and microscope may be used. The statement made that the maximum diameter of such a wire should not exceed 0·004 in. is again illustrative of the practical nature of the instruction given. This workshop point of view is maintained throughout.

The Spectrochemical Analysis of Metals and Alloys. By F. TWYMAN, F.R.S. London: Charles Griffin and Company, Limited. [Price 21*s.*]

THE possibilities of qualitative spectrum analysis were established when Kirchhoff and Bunsen recognised, about 1860, that the line emission spectrum of an atom is characteristic of that atom and of its condition of excitation, and employed spectroscopic methods in the isolation of cæsium and rubidium. The possibilities of quantitative spectrum analysis were first envisaged by Lockyer in 1874. Subsequent developments, which have confirmed its feasibility, vindicated its reliability and widened its scope, have depended primarily upon the design of improved equipment and on the careful working out of the most appropriate procedures. To both, Mr. Twyman has made fundamental contributions, and his unique experience has enabled him to produce a work of outstanding importance.

The book is divided into two parts. Part I opens with a historical introduction covering the period from Newton's discovery of the dispersion of light, in 1672, to the present time. These classical contributions well repay study, and the necessary references are provided. Since some of the earlier references are not easily located, however, it would have been helpful to mention such more widely available reprints as that of Newton's *Optics*,* and of Fraunhofer's fundamental paper in the Ostwald *Klassiker* series. Chapter II, contributed by Mr. A. C. Candler, covers the elements of atomic spectrum theory. Though quite brief, it sets out clearly all that is essential for the practical spectroscopist. It is regrettable that theoretical spectroscopists have fallen into the habit of referring to "energies in cm.$^{-1}$." Consideration of the practical aspects of the subject is begun in Chapter III, which deals with spectrographs and accessory apparatus. Having pointed out the disadvantages of grating spectrographs, the author explains in detail the relative merits of the "medium" and "large" types of quartz-prism spectrograph. The individual components are examined in turn, valuable hints being given on such matters as the testing of a slit, and the selection and use of condensing and positioning lenses. Quantitative spectrochemical analysis is based upon the possibility of correlating the relative intensities of certain lines in a spectrogram with the percentages of the elements responsible for them. This intercomparison is carried out with the aid of a microphotometer, preferably of the non-recording type. The main features of an instrument suitable for this purpose, and the technique of using it, are described in Chapter IV, which also deals with the properties of photographic plates and the importance of careful standardisation in methods of processing them.

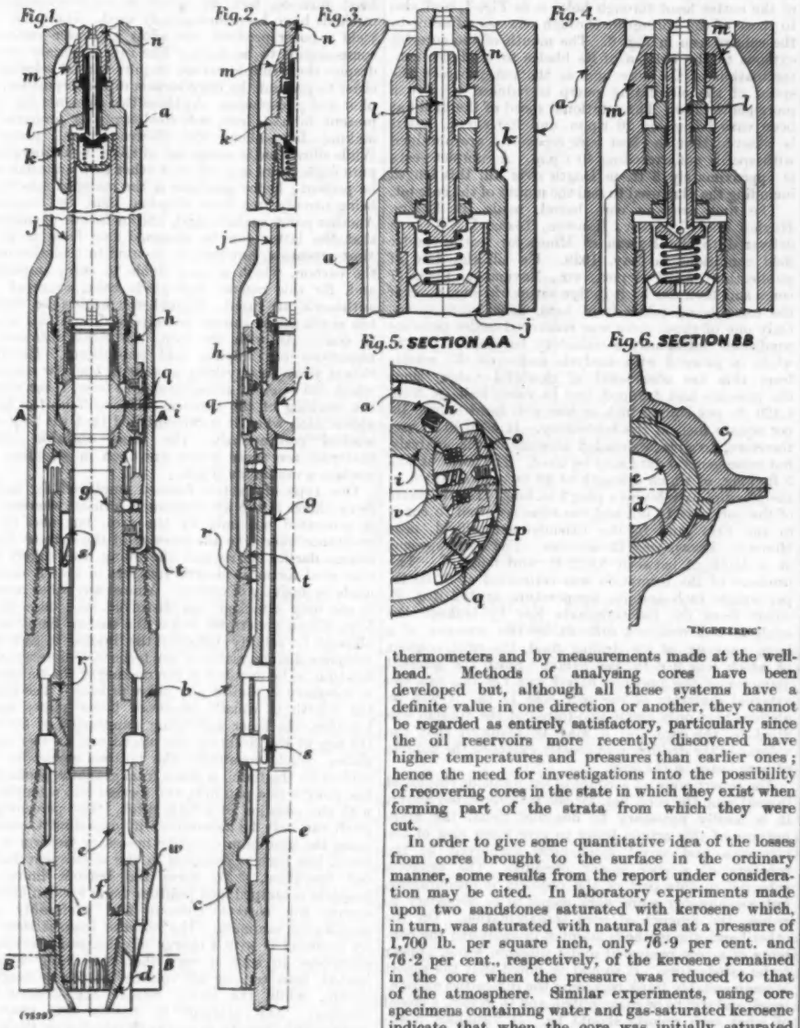
Part II opens with a discussion of the methods of exciting emission spectra. Of the four main means of inducing a substance to emit radiation suitable for its spectroscopic analysis—the flame, the arc, the spark and the vacuum-discharge tube—the arc and spark are the more important and the arc is the more sensitive. In the arc all the metals and five of the non-metals yield characteristic spectra, while in the spark many more of the non-metals are detectable. The means of ensuring that the source shall function in a controllable and reproducible manner are stressed. These depend partly upon the choice of the electrical operating conditions and partly upon the character of the electrodes. Depending upon circumstances, these electrodes may be cast rods with shaped ends, and either of the same or of two different materials, or they may consist of strips cut from a sheet. Where there is a tendency for the constituents within a sample to segregate it may be necessary to bring the material into solution and then to prepare the electrode by drying a carbon rod which has been impregnated with the solution. Chapter VI details the procedure for taking spectrograms and for interpreting the results. It includes a list of standard works of reference, both texts for consultation and tables and charts to assist in the identification of spectral lines. The next chapter provides a clear exposition of the various techniques employed in spectrochemical analysis and one sufficiently critical to permit a rational choice of the most appropriate method to be made.

The types of problem to which spectrochemical analysis is specially suited are considered in Chapter VIII. Experience has shown it to be particularly valuable in investigations relating to alloys, where it is sufficiently sensitive to detect traces of constituents in such minute proportions as to be beyond the limits of reliable chemical analysis. With constituents present in amounts up to 4 per cent. or 5 per cent. the accuracy of its estimation lies between 2 per cent. and 7 per cent. Moreover, once the preliminary details of a suitable procedure have been elaborated, determinations can be carried out very rapidly, since no question arises of separating out the constituents from the sample. The spectrochemical method is most effective, accordingly, where chemical methods prove least serviceable; indeed, within this region, it has become legitimate to suspect a chemical analysis which differs markedly from a spectrochemical analysis. The chemical methods, however, still retain their superiority when the major constituents in an alloy have to be determined. In Chapter IX, separate sections are devoted to the various metals, arranged alphabetically. Methods of conducting spectrochemical analyses of each of these metals and of their chief alloys, as developed by leading authorities, are given. These should go far to convince any engineer who may harbour doubts concerning either the scope or the practicability of this type of analysis. To anyone interested in spectrochemical analysis, this book can be unreservedly recommended. Few works in any field can justly be claimed to be indispensable, but this assuredly is one.

* London: G. Bell and Company, Limited. (1931).

INSTITUTION OF ELECTRICAL ENGINEERS.—The Council of the Institution of Electrical Engineers has awarded premiums, each of a value of 10*l.*, to Mr. W. H. Coats, B.Sc., and Mr. W. E. Darby, in respect of students' papers read during the 1940-41 session. Further students' premiums, each of a value of 5*l.*, have been awarded to Mr. F. B. Atkinson, B.Eng., Mr. R. Bruce, M.Sc., Mr. D. B. Corbyn, Mr. R. D. Haigh, Mr. J. Hare and Mr. M. J. H. Lemmon.

PRESSURE CORE-BARREL.



OIL-WELL CORE EXTRACTION UNDER PRESSURE.

CONSIDERABLE progress in the development of a new technique in the recovery of borehole cores from oil wells has recently been made in the United States, and an account of the work, as described in a report by Messrs. D. B. Taliaferro and R. E. Heithecker, published by the Bureau of Mines, under the title *Report of Investigations, R.I.* 3481, may be of interest. As is well known, the deep strata in oil-bearing regions are under a high pressure and the withdrawal of a core from this region inevitably results in the loss and contamination of a large amount of the material during ascent and when the core reaches the surface, where it is exposed to atmospheric pressure only. Analysis of such a core thus gives misleading information regarding the physical and chemical constitution of the formation being investigated, and the data available are insufficient to enable reliable estimates to be made of the quantity and availability of the oil and gas within a natural reservoir. In consequence, the efficiency of the means subsequently adopted for extracting the oil and gas from the borehole may be adversely affected.

The new technique involves the withdrawal of a deep-seated core in a vessel which is automatically sealed, *in situ*, so that, when the core reaches the surface it is, as far as possible, in its original condition and analysis is rendered much more accurate. It must not be supposed that prior to the development of the pressure core barrel no attempts had been made to assess bore-hole conditions and that the cores were only examined in their geological aspect. Actually, the producing characteristics of oil reservoirs have been determined by means of sub-surface pressure gauges and thermometers and by measurements made at the well-head. Methods of analysing cores have been developed but, although all these systems have a definite value in one direction or another, they cannot be regarded as entirely satisfactory, particularly since the oil reservoirs more recently discovered have higher temperatures and pressures than earlier ones; hence the need for investigations into the possibility of recovering cores in the state in which they exist when forming part of the strata from which they were cut.

In order to give some quantitative idea of the losses from cores brought to the surface in the ordinary manner, some results from the report under consideration may be cited. In laboratory experiments made upon two sandstones saturated with kerosene which, in turn, was saturated with natural gas at a pressure of 1,700 lb. per square inch, only 76·9 per cent. and 76·2 per cent., respectively, of the kerosene remained in the core when the pressure was reduced to that of the atmosphere. Similar experiments, using core specimens containing water and gas-saturated kerosene indicate that when the core was initially saturated with 15·6 per cent. of water and the remaining pore space was filled with kerosene saturated with natural gas at a pressure of 1,200 lb. per square inch, 32·1 per cent. of the kerosene (representing 27·1 per cent. of the volume of the pore space in the core) was expelled from the core. In another test, with the core having initially a water saturation of 60 per cent., 73·3 per cent. of the kerosene saturation (representing 29·3 per cent. of the pore space of the core) was expelled. The significance of the latter tests lies in the fact that well-boring is carried out with a medium, either water or mud-laden water, which is kept in circulation to remove the cutting debris as it is formed. The core, as hitherto normally recovered, is thus effected by the fluid, either by direct penetration through its peripheral surface or by the filtration of the medium into the strata ahead of the drill, the core being thus cut from pre-contaminated material.

Experience indicates that of these two sources of contamination the last-mentioned is probably the more serious and difficult to cope with. Oil may be used as the circulating medium instead of water with a view to eliminating water contamination, but it is clear that this expedient renders it unsuitable for determining accurately the oil content of the cores. An alternative method which, however, has not apparently reached a practical stage, is to use some inert medium of a specific gravity such that it will remain in the bottom of the bore and is insoluble in both crude oil and water. The cuttings, on rising to the top of this layer, are picked up by the normal drilling mud lying above it. The objections to the scheme are two-fold: firstly, its cost and, secondly, the risk of infiltration into the unpierced strata, with consequent contamination of the subsequently cut core. This latter drawback, though it would be easy enough to identify the medium in the extracted core, would probably alter the fluid content to a degree sufficient to vitiate the results. The investigations described in the report have been hitherto mainly confined to the development of the apparatus for recovering the core under pressure and the problems of contamination have taken a secondary place, the above summary having been made in order to give a general idea of the problem as a whole. We now propose to describe the pressure core barrel itself.

The construction of the apparatus is shown in Figs. 1 to 6, on this page. It consists of a barrel *a*, screwed at the top for coupling to the normal drill pipe, and at the bottom to take the bit body *b*, which, in turn, is screwed to take the cutter head *c*. The cutter head, as will be clear from Fig. 6, has four blades. These cut the well bore, the core itself being cut by the smaller four-bladed bit *d*. This bit is rotated by the cutter head by means of the four splines seen in Fig. 6, but is free to move axially in relation to that head. The bit is screwed to a tube *e*, its position axially being determined by a sleeve *f*, which butts against a shoulder on *e*. Four screws pass through the cutter head *c* into the sleeve *f*. These are designed to shear through at a certain stage of the operation and one of them is shown in this condition at the bottom of Fig. 1, on the left. The finger-like strips seen in this view at the mouth of the core bit *d* are strips of spring steel which allow the passage of a core upwards but prevent it moving downwards after it is in the barrel. The tube *e* slides on a tube *g*, as will be gathered from a comparison of Figs. 1 and 2, the latter showing tube *e* in its fully-extended position and the former in its fully-retracted position. The tube *g* is screwed into a cylindrical valve body *h* in which rotates on a horizontal axis, a spherical valve *i* having a central hole. This plug valve is seen in the closed position in Fig. 1, and in the open position in Figs. 1 and 5. The valve is provided with a fixed seat below and with a spring-loaded seat above.

Into the upper part of the valve body *h* is screwed the pressure barrel *j*, a gland being provided above the joint to ensure pressure tightness. At about the level of this gland there will be seen, in both Figs. 1 and 2, some small hinged levers. These are free to open upwards to let the cut core pass into the pressure barrel and thereafter to prevent it from falling out again. It will be clear that, when the valve is open, there is an uninterrupted passage from the core bit mouth to the pressure barrel. But, it will also be apparent that an exit must be provided for the water or drilling fluid displaced by the core on entry. This exit is best seen in Figs. 3 and 4. The pressure barrel *j* is closed by a screwed cap *k* through which passes the hollow valve stem *l*. The stem terminates in a mushroom vent valve opening downwards and having several ports immediately under the valve disc. The vent valve is spring-loaded, the spring being contained in a perforated cage attached to the cap *k*. The valve stem projects some distance above the top of the cap and is screwed and provided with a nut. The projecting end of the stem is protected by a hood *m*, which is free to slide on the tube *n*. This tube is secured to the outer barrel *a*, and forms the outlet from the pressure barrel; it also provides the means for opening the vent valve. The vent valve, as shown in Figs. 1 and 4, is open because the pressure barrel assembly has been pushed up until the stem nut is in contact with the end of tube *n*, the resistance of the spring being thereby overcome and the valve forced downwards. In Figs. 2 and 3, it will be clear, by a comparison of the positions of the hood *m* with the edge of the necked part of the outer barrel in both figures, that the inner barrel assembly has moved downwards thus freeing the valve, which is then closed by the spring under it.

The several movements referred to above will be understood when the manipulation of the apparatus is described; in the meantime, it is necessary to consider the means provided for opening and closing the plug valve *i*, closure taking place when the cut core is in the pressure barrel. The short spindle of the plug valve is provided with a small spur wheel, *o*, in Fig. 5, meshing with a rack *p*. The rack, which must necessarily have an axial movement relative to the valve body *h*, is held in place by a guide *q*, with dovetailed sliding surfaces, attached to the body. The rack is formed with teeth on both edges, and the guide engages with the dovetailed internal slot. The rack is attached to a sleeve *r* which, it will be seen by comparing Fig. 1 with Fig. 2, has a sliding motion on the lower part of the valve body *h*. The sleeve *r*, in addition to giving a traversing movement to the rack, forms a guide for the tube *e*. The movement of sleeve *r* is derived from that of tube *e* by means of three latches *s* round the circumference. The slotted sleeve *t* is merely a support for the pressure barrel assembly.

The functions of the parts described above may now be explained and can be understood by following the operating procedure of the apparatus as outlined below. When the barrel is lowered into the bore hole, the parts

are substantially in the position occupied in Fig. 1, except that the core bit projects a little farther beyond the head than shown, since the shear pins then pass into the sleeve *f*. The relative positions of the shear screw and the groove in which it enters, as indicated in Fig. 1, will give some idea of the amount of this projection. The vent valve, though shown open in Fig. 1, is closed initially, but the plug valve is open. The upper part of tube *e*, carries the three spring-loaded latches *s*, above referred to. These latches are held in a vertical position when the apparatus is lowered into the bore and when the core is being cut, since they lie between the sleeves *g* and *r* in Fig. 1. When the core bit touches the bottom of the bore the whole weight of the apparatus and of the drill pipe above it comes on the shear screws, which are thus cut through and the outer barrel moves downwards until the cutter head rests on the bottom. The pressure barrel assembly settles down until the bottom of the valve body *h* makes contact with the top of tube *e*, as shown in Fig. 1. The relative movement between the outer barrel and the pressure barrel forces open the vent valve through a distance of about ¼ in., this opening occurring just before the outer barrel comes to rest on the bottom. Drilling through the strata then proceeds and the core as it is cut passes into the pressure barrel, the water with which the barrel was previously charged being expelled through the vent valve.

The core having been cut, the apparatus is lifted from 10 ft. to 15 ft. off the bottom, and, since the shear screws are no longer operative, the outer barrel moves upwards first. This it does for a distance of about 8 in., relative to the core bit assembly, when a shoulder on the inside of the outer barrel comes into contact with a shoulder on the outside of tube *e*, as shown at the bottom of Fig. 2. The two parts then move upwards together, but in the meantime, the latches *s* have been withdrawn from inside the sleeve *r* upon reaching the end of which they spring outwards under the edge of the sleeve as indicated by the dotted outline in the lower part of Fig. 1, their outward movement, however, being limited by a short fixed sleeve in the bit body *b*. The relative movement of the tube *e* and the outer barrel also causes the core to be broken at the catches above the plug valve, the part in the pressure barrel being retained by the catches and the lower part falling clear of the valve. The lifting of the apparatus also causes the vent valve to close.

At this point of the operation the apparatus is clear of the bottom of the bore and the core is in two parts having a space between them. The interior of the pressure barrel is subject to the pressure in the strata. The next stage is to close the plug valve, which is done by setting the core bit on the bottom with the full weight of the equipment above it. Before this is effected, however, the apparatus is raised and dropped a few feet several times to shake down the tube *e* in case the entrance of sand may have caused sticking. The final setting of the core bit on the bottom causes the tube *e* to be pushed upwards, its projecting latches coming into contact with the bottom of sleeve *r*, forcing that sleeve upwards and, with it, the plug valve rack. The traverse of the rack is limited by a stop so that the plug valve is turned through 90 deg., that is, into the closed position of Fig. 2. It now remains to ensure that the valve cannot be re-opened. Reference to Fig. 2, will show that the sleeve *r* in the region of the rack carries a spring-loaded ball entering a recess in the lower part of the valve body *h*. When the traversing movement takes place, this ball drops into another and higher recess, as indicated in Fig. 2. This figure also illustrates another safety device, for it will be seen that the latch *s* is now folded downwards by its spring, and, in consequence, any further movement of the tube *e* can not affect the sleeve *r*. This release of the latches is effected by the upward movement of tube *e* to the point at which they escape the restraint of the short sleeve seen as confining them in the dotted lines of Fig. 1. The weight of the pressure tube assembly and the pressure of the vent valve spring force down that assembly on to the top edge of the sleeve *t*; and the spring then closes the vent valve. In this condition the apparatus is ready for withdrawal from the bore. On reaching the surface the bit body *b* is unscrewed from the barrel *a* and the unsealed part of the core, which is then at atmospheric pressure, can be removed for examination, further dismantling enabling the pressure barrel with its contents to be removed also.

In order to condense the account of the actual core-cutting operation, several points were only lightly touched upon. These may now be briefly amplified. The pressure tube was referred to as being filled with water. This is retained by a plug in the mouth of the core bit, the plug being forced upwards subsequently by the entering core. The water is introduced, when preparing the apparatus, through the small non-return ball valve *v* seen in Fig. 5. The sealing of the inner assembly during lowering is, of course, necessary to prevent debris from entering the pressure barrel. When the apparatus has reached within a few feet of the bottom of the bore hole the mud-fluid circulating pump is started. This flushing fluid is directed to the blades of the cutter head through holes *w* in Fig. 1, and also to those of the boring bit through recesses adjacent to the splines seen in Fig. 6. The mouth of the core bit extends to the bottom of its blades to minimise contamination of the core and as the cut proceeds the speed of the circulating pump is reduced to give a more gentle flow. The rotational speed of the drill has been varied between 20 r.p.m. and 100 r.p.m., but it is believed that the best core recoveries are obtained with speeds not exceeding 40 r.p.m. A complete core is approximately 5 ft. in length over all, this length including the plug used to seal the mouth of the core bit.

The first pressure core barrel, made by Messrs. Hughes Tool Company, Houston, Texas, U.S.A., was delivered to the Bureau of Mines for testing under field conditions in May, 1939. Up till the date of publication of the Report, viz., November, 1939, 17 cores had been cut by it in five series of tests, none of the cores being taken from hard, dense, formations. Only one of these cores was recovered under pressure conditions sufficiently satisfactory to make it worth while to proceed with analysis and even the results from this are considered of doubtful value, since the pressure had dropped, due to valve leakage, from 1,420 lb. per square inch at the well head to 965 lb. per square inch in the laboratory. It is of little use, therefore, to give a detailed account of the analysis, but some general data may be cited. The core cut was 5 ft. long, of which a length of 33 in. was retained in the pressure barrel, plus a plug 3 in. long. The diameter of the core was 1⅛ in., and the time required to cut it in the Frio sand in the Friendswood oilfield, near Houston, Texas, was 12 minutes. The core was cut at a depth of between 6,022 ft. and 6,027 ft. The pressure of the formation was estimated at 2,700 lb. per square inch and its temperature at 162 deg. F. Apart from the indeterminate loss by leakage the analysis was rendered difficult by the presence of a large quantity of the drilling fluid, the mud content of which was 9·6 lb. per gallon. Since the internal diameter of the pressure barrel was 1$\frac{13}{16}$ in., and the external diameter of the core was 1⅛ in., it will be obvious that only about two-thirds of the volume was filled by the core, and it may be assumed that the volume of the drilling mud greatly exceeded the volume of pore space in the core.

The report gives an account of the methods employed in analysing the core, but, for the reasons stated above, it is hardly necessary to describe them, the main purpose of this article being to give some idea of the ingenious and novel mechanism employed in the recovery of a core under pressure. The progress achieved in this part of the problem is encouraging, but considerably more work seems to be necessary to reduce the amount of core contamination. On the other hand, the methods adopted in analysing the contents of a core recovered under pressure would appear to be satisfactory. It should be noted that the report is commendably frank regarding the difficulties encountered, and still to be surmounted, and is, in fact, a model of what such reports should be. It visualises possibilities of securing more accurate data regarding the oil and gas content of an oil reservoir than has been possible in the past, and suggests that these data may be of great value in estimating oil reserves, but it does not attempt to convey any idea that, up till the time of its publication, the technique of pressure-core recovery has been completely worked out.

THE MANUFACTURE OF FERRO-SILICON.

THE use of ferro-silicon as a deoxidising agent in steel manufacture and in the production of acid-resisting materials, employed for a wide variety of plant and equipment in chemical works, are well known. Ferro-silicon, however, is also used for making anodes for certain electro-deposition processes, as the material is more or less insoluble. These anodes are employed in connection with the preparation of various chemicals by electrolysis, and with the electro-deposition of metals from reclaimed solutions. Formerly, platinum anodes were employed for this purpose, but owing to their cost alternative cheaper materials have been substituted, including antimonial leads, graphites and hard artificial carbons, carborundum, oxides of lead and manganese, and magnetite. Many of these materials are insoluble, whereas ferro-silicon is attacked under certain conditions necessitating the renewal of the anodes. Ferro-silicon anodes, on the other hand, have the advantage that they may be prepared on site as required, provided that the necessary furnace equipment is available. In one large factory, a small electric furnace is employed for casting anodes, specifically for this purpose, from the raw products, namely, carbon, silica, and iron. All broken, corroded, or otherwise defective anodes, are returned to the furnace for remelting.

Ferro-silicon was formerly produced entirely in the blast furnace, but, in recent years, electro-thermal methods have been increasingly used. These not only yield a purer product, but allow a greater variety of compositions to be made. The raw materials needed, despite their simple nature, require careful selection in order to prevent the introduction of the impurities, sulphur and phosphorus. As these two elements are often present in cast iron, soft-steel scrap is preferred for making ferro-silicon by electro-thermal processes. While silica sand is composed of silica in comparatively pure form, there is a risk that other rock materials may be present; hence quartzite is the material selected, it being usually free from alumina, lime, and magnesia. Another point against sand, and in favour of quartz, is that the latter can be obtained free from moisture. Most attention, however, is devoted to the selection of the carbon, which is very liable to carry impurities, and, for this reason, high-grade coke, charcoal, and anthracite are used. Should the anthracite contain too much ash it cannot be employed, and this applies to coke. As with the iron, the most unfavourable impurities are sulphur and phosphorus. Moreover, should there be anything present in the raw materials which can cause an infusible slag to form, it can disturb the working of the furnace. This will be the better appreciated when it is remembered that the process is worked continuously. The most suitable carbon materials are those which are open in structure and contain a minimum of ash.

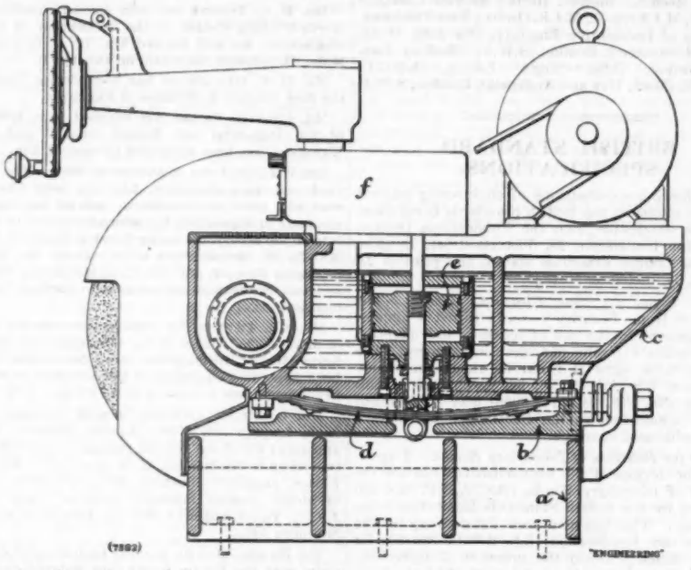
One type of electric furnace employed for making ferro-silicon is the arc-resistance furnace wherein heat is generated not only by the arcs, but also by the resistance offered to the passage of the current by the charge itself. As regards the lining, this differs from that used for most electric furnaces in that it must be made exclusively of carbon. Almost any other material is not only attacked, but dissolved, and once molten ferro-silicon penetrates below the carbon lining and is allowed to solidify between the bricks, it can cause complete disintegration of the furnace. More attention has thus to be devoted to the making of the lining than is necessary in almost any other process. The shell of the hearth is usually made of boiler plates riveted together, the inner wall being constructed of firebrick. On top of the firebrick are placed one or two copper plates which constitute the bottom electrode. The carbon for the lining is made from graphite, ground to a fine powder in a pan-mill, and formed into a tough mass with the addition of a little pitch. The percentage of pitch can only be ascertained by experiment, since by using the minimum quantity necessary to form a good bond, less time is occupied in the subsequent burning out operation. To form the bottom lining, the graphite is tamped into position using wooden blocks to ensure the correct contour and preferably using mechanical rammers. The rammed mass is then fired by covering it with a charge of coke, and lowering the electrodes in such a way that the lining is gently heated, thus causing all volatile matter to evaporate slowly, while the lining retains the desired rigid exterior. Any attempt to hasten this treatment unduly only results in cracks developing in the lining.

The upper electrodes are of the usual cylindrical graphite type, but require to be housed within more or less tight-fitting economisers. The reason for this is that air must be excluded as far as possible, and the economiser consists of two sections. The lower section which literally enters the hearth is water-cooled, while the upper section is equipped with asbestos cord coiled in such a manner that the electrode can only be raised and lowered by pressure. In this manner, with a well-sealed tapping spout, there is little danger of air entering the furnace. The upper electrodes are raised and lowered by mechanism outside the furnace, and operated by double square-threaded screws, which further limit any undue movements. Bottom connections are made by leading cables from 'bus-bars to water-cooled boxes which are connected to the copper plates arranged on the top of the firebrick lining. Much research has been carried out in an endeavour to improve the construction of the bottom connections so that they will give a long period of useful service. Despite every care, however, a time comes when the corrosive charge breaks through the carbon lining, and unless adequate precautions be taken, the bottom electrodes, cooling arrangements and connections, are ruined, and require replacement. The dome-shaped roof is made of firebrick, as also are the side walls, and these are held together by means of fireclay grout. All old electrodes are collected, broken up, and returned to the pan-mill for making fresh bottom linings.

Charging the furnace simply consists of shovelling in the quartzite, high-grade coke, and soft-steel scrap, and as a rule, in the case of small furnaces, none of the pieces should exceed about one inch in diameter. The upper electrodes are then lowered until connection is made. As, despite every care, some gaseous matter may be evolved, the hearth is not completely sealed

GRINDING WHEELHEAD WITH HYDRAULIC FEED.

MESSRS. FITCHBURG GRINDING MACHINE CORPORATION, FITCHBURG, MASS., U.S.A.



up for the first few minutes of the operations, after which all slight spaces at the tapping spout are closed. More variations occur in the current than with almost any other type of electric hearth, and this is due to the condition and disposition of the carbon content. Once the highly oxidisable mass is covered with a layer of slag, there is less danger of air injuring the charge, and it is then that the furnace is tapped and fresh material added. In this manner the process proceeds continuously without interruption. The molten charge is tapped into carbon moulds in which the ferro-silicon is cast in the form of slabs. After cooling, the metal is broken up into pieces approximately 4 in. in diameter and the resulting fine material is screened and disposed of separately.

Current yields and expenditure probably fluctuate more widely when making ferro-silicon than when producing most other ferro-alloys on account of the varying resistance offered by the nature of the charge. The conductivity of the type of carbon used exerts a considerable influence on the ratio of voltage to current. Thus, where feebly-conducting charcoal is used, this ratio is higher than for anthracite or high-grade coke, with corresponding variations in current density. Current yields are directly influenced by the percentage of silicon present in the resulting alloy, because a larger consumption is necessary for reducing the extra silica. Thus, while the 25 per cent. silicon grade can be produced at 2·3 kWh per lb., the 70 per cent. grade requires 16 kWh using a small arc-resistance furnace of some 200 kW. As with practically all other electro-thermal reactions, the larger the furnace the lower is the corresponding current consumption, and the 70 per cent. alloy is claimed to require only 6·5 kWh per lb. in certain large units. The richer alloys, and particularly the 90 per cent. variety, as required for dynamo plates, etc., necessitates the application of a larger load; only economically obtainable in large furnaces. In small hearths, heat losses are more considerable than in large furnaces; furthermore, electrode consumption varies on the same lines, ranging from as much as 200 lb. in a small furnace to little more than 90 lb. per ton of ferro-silicon produced in the Héroult furnace.

BRITISH EXPORTS TO THE UNITED STATES.—The President of the Board of Trade, in order to co-ordinate and stimulate the efforts which are being made, both in this country and in the United States, to maintain the fullest possible volume of export trade to the United States, has decided, after consultation with H.M. Ambassador at Washington, to appoint to that country a representative of the Industrial and Export Council. Sir Kenneth Lee, who is at present in the United States, has accepted the President's invitation to accept this appointment. He will keep in close touch and work in co-operation with the Commercial Counsellor of H.M. Embassy and also with H.M. Consul-General in New York, and the British Empire Chamber of Commerce. Sir Kenneth's headquarters will be at 587, Fifth-avenue, New York, in the same building as the British Empire Chamber of Commerce.

GRINDING WHEELHEAD WITH HYDRAULIC FEED.

IN the wide range of grinding machines manufactured by Messrs. Fitchburg Grinding Machine Corporation, 1,503, Walnut-street, Fitchburg, Massachusetts, U.S.A., considerable use is made of the unit known as the "Bowgage" independent wheelhead developed by the firm and illustrated in the accompanying figure. The method of feeding the wheel up to the work is of interest as no lead-screw motion is employed, the wheelhead being traversed by the deflection of a spring under hydraulic pressure. The wheelhead is termed "independent," as it is self-contained and, with the provision of a suitable base, may be fitted to most types of grinding machine, as well as to those manufactured by the firm. Such a base is indicated at *a* in the figure, the wheelhead saddle *b* being traversed across it by the usual screw motion when rapid movement up to or away from the work is to be made.

The actual feeding movement, however, is not effected by this motion, the wheelhead proper, indicated at *c*, being capable of limited traverse on the saddle. The wheelhead and saddle are connected by the leaf spring *d*, which is attached to the former at its left-hand end and to the latter at the right-hand end. The straightening out of this spring, it is clear, will result in a movement of the wheelhead to the left, that is, in a feeding motion. This straightening is effected by the upward movement of the piston *e*, to the underside of which oil is pumped under pressure from the reservoir in the head. Since the volume of the cylinder is large, the amount of oil delivered to it in order to effect movement of the piston is large relatively to the piston travel, and, in consequence, a precise degree of control of the movement is attainable. The rate of feed is not uniform, being faster at the start and gradually slowing down as the final wheel position, which determines the size of the work, is reached. When this point is just about to be reached, the ratio of the vertical movement of the piston to the horizontal movement of the wheel is approximately 250 to 1. Even supposing, then, that the piston movement was not arrested precisely as required, the resulting error in the final sizing position of the wheel would be infinitesimal.

The oil pressure is derived from a hydraulic pump with a capacity of 2·5 U.S. gallons per minute. The oil from the cylinder is returned to the reservoir, which holds 8 U.S. gallons. The admission of oil to the cylinder is regulated by a valve, which is set, by means of a dial on the control panel *f* of the wheelhead, to give the desired rate of feed. A Telechron clock-controlled time delay switch, also on the panel, can be set to determine the length of time for which the wheel is held in its final position, known in American practice as the "spark-out" time. Another graduated dial, operated by a small handwheel, is set for the amount of stock it is desired to grind off, the maximum being $\frac{1}{2}$ in. on the diameter. When the several settings have been made, the cycle is started by the depression of a push-button, the movements then occurring in the following sequence: rapid traverse, slow grinding feed, grinding dwell, and rapid return to the starting position. The feed movements can be controlled to 0·0001 in., and, it is claimed, can be maintained consistently since there are no bearings to wear or screws to develop backlash. No wear is likely on the roller connection between the piston rod and leaf spring, and in any case, owing to the high ratio mentioned above, any slackness at this point would not appreciably affect the wheel feed. It may be noted that the handwheel seen in the upper part of the figure is for hand movement of the grinding wheel when setting up; it actuates the saddle and not the wheelhead.

It is not proposed to describe the different types of grinding machine made by Messrs. Fitchburg and distributed in this country by Messrs. Broadway Engineering Company, Limited, Carlisle-road, Hendon, London, N.W.9, in which the "Bowgage" head is embodied, though two or three examples may be mentioned to give some idea of the applicability of the unit. It is fitted, for example, to plunge-cut grinding machines of both the centre and chucking types with a 3-in. spindle and wheels up to 24 in. in diameter; and also to a heavier machine with a spindle 5 in. in diameter carrying either a 24-in. wheel with an 8-in. width of face or a 30-in. wheel with a 3-in. face. One of the numerous special applications is to a grinder for forming the curved profile of die-heads for tube piercing. The die-heads are of cast steel and are finish-ground from the rough. A master former is attached to the sliding table and as this reciprocates the wheelhead is held hydraulically against the former. There is a continuous infeed of the "Bowgage" head as the wheel follows the former, so that the contouring operation is automatic. Another example of its application is to a machine for grinding the spherical backs of differential gears, the cycle being automatic, while machines with two, or even three, heads for long work with several surfaces to be ground are also made.

THE "AIRGRAPH" LETTER SERVICE.

SOME years before the outbreak of the present war, the Kodak organisation, in conjunction with Imperial Airways, Limited (subsequently known as British Overseas Airways, Limited) and Pan-American Airways, evolved a system for the economical transmission of letters, which was intended to be used in connection with the Transatlantic air service. Although not yet employed for Transatlantic mails, the system, which is known as the Airgraph letter service, has been adopted by the Post Office for bringing letters to this country from H.M. Forces serving in the Middle East, and we understand that a similar service in the opposite direction will be instituted as soon as the necessary technical arrangements can be completed.

Letters intended to be transmitted by this system are written on the upper portion of a special form measuring 8 in. wide by 11 in. deep, a part of the area near the bottom of the form being reserved for the address. Batches of such letters are fed into a Recordak camera, in which each is photographed on to a roll of miniature film, 16 mm. in width; 100 ft. of this film can take the images of about 1,700 letters. The film is developed in the country of origin and is carefully examined as it leaves the developing machine; Fig. 1, on page 10, shows this part of the work being carried out. The rolls of film negative are transported by air to this country, where the film images are enlarged on to a continuous strip of photographic paper in the machine illustrated in Fig. 2, this machine being capable of dealing with 60 letters per minute. From the enlarging machine the strip of exposed paper is passed into the developing machine, shown in Fig. 3, in which it is developed, rinsed after development, fixed and washed. The final drying operation is carried out on a rotating drum, as shown in Fig. 4, the wet strip being passed on to this drum directly from the developing machine. When dry, the individual letters are cut from the strip and folded, and each is then placed in an envelope having an opening through which the address can be seen, and delivered to the addressee by the ordinary postal service. The letter, as delivered, is about one quarter of the area of the original form, but both the message and the address are quite clear.

The system was adopted by the Post Office, working in co-operation with Messrs. Kodak, Limited, Wealdstone, Middlesex, the War Office, the Air Ministry, and the Admiralty, with the object of expediting and cheapening homeward postal communication from the British Forces in the area previously mentioned. That this object has been attained will be clear from the fact that Airgraph letters take less than a fortnight in transit and the charge made is only 3*d*. The low charge is possible because of the relatively small bulk and weight of the film negatives in comparison with ordinary letters. It may be noted that the negatives of 4,500 letters weigh only 1 lb., whereas the weight of

the same number of ordinary letters would be about 1½ cwt. The system has been in operation for nearly two months, the first batch of 50,000 letters having been received in this country on May 13, and all the necessary enlargements made and dispatched by May 16. Since that time, we are informed, a batch of 90,000 letters has been dealt with between the Monday and Friday of one week.

JOINTING MORTARS FOR BRICKWORK.

THE demand for cement for vital constructional work at one time made supplies rather short for structures of the second order of importance. This situation has now been rectified, but that is no reason why cement, like other things, should not be used as economically as possible and full advantage taken of alternative materials. The jointing of brickwork, for which much cement is employed, covers a wide field and concerns a large number of users. These, who range from the big contractor to the small builder, will probably find the latest Wartime Building Bulletin* of the Department of Scientific and Industrial Research of both interest and value. It deals with jointing mortars of all types.

In view of the nature of most of the work being carried out, the relative proportion of brickwork being laid in cement mortar is above the average and as any structure may possibly be subjected to the effect of explosions at the present time, the Bulletin suggests that when ample supplies of cement are available stronger mortars than usual are justifiable for almost any purpose. As, however, conditions may quite possibly arise in which economy in the use of cement is again necessary, a table of mixes is given in which the minimum allowable cement content is specified, a warning being added to the effect that when these mixes are used extra supervision may be necessary to ensure that the specifications are properly adhered to.

The Bulletin deals separately with five main types of mortar: cement and sand; cement and lime and sand; lime and sand; black mortars and mill mortars; and gypsum and anhydrite products and sand. Structures are divided into three classes: (*a*) those required to have early strength; (*b*) those ultimately required to have considerable strength; and (*c*) those required to have only a small degree of strength at any time. Normally all air-raid shelter work is regarded as falling under class (*a*) and it is recommended that a cement-sand mix of 1 to 3 or 1 to 4 should be used, especially in the winter. It is added, however, that under favourable conditions a good cement-lime-sand mortar may be substituted. This latter type of mix has some advantages over a straight cement-mortar for structures requiring a reasonable degree of ultimate strength, but in which early strength is not so important. It offers better resistance to rain penetration, and having better workability, increases speed and reduces labour costs.

The type of lime used has much influence on the rate at which lime mortars attain strength in brickwork. With non-hydraulic limes the development of strength is very slow. Semi-hydraulic limes are better, but it is only hydraulic limes, such as blue lias, which are recommended as a substitute for cement-lime-sand mortars in normal circumstances. Magnesium and dolomitic limes, it is stated, should be considered as non-hydraulic. Black mortars, made by grinding brick rubble or ashes with lime in a pan-mill, can be used for normal brickwork, where strength is not of critical importance, but as the soundness depends on the quality of the ingredients, the absence of old plaster on the brick, for instance, care is required when material from demolitions is used. Mortars made from gypsum and anhydrite products are reasonably strong, but lose much strength when wet. They are satisfactory for internal walls, but should not be used in the open.

THE FRANKLIN INSTITUTE.—The Committee on Science and Arts of the Franklin Institute, Philadelphia, Pennsylvania, has awarded the Louis E. Levy Medal for 1941 jointly to Professors J. M. Lessels, B.Sc.(Glas.), M.I.Mech.E., and C. W. MacGregor, Ph.D., for their paper "Combined-Stress Experiments on a Nickel-Chromium-Molybdenum Steel," published in the August, 1940, issue of the *Journal of the Franklin Institute*. Both the recipients are associate professors in the Department of Mechanical Engineering, Massachusetts Institute of Technology. Professor Lessels is a native of Dunfermline, Fifeshire, and was awarded a T. Bernard Hall Prize of the Institution of Mechanical Engineers in 1926.

* *Building Research Wartime Building Bulletin No.* 16. *Jointing Mortars for Brickwork.* London: H.M. Stationery Office. [Price 3*d.* net.]

INSTITUTION ELECTIONS.

ASSOCIATION OF CONSULTING ENGINEERS.

Members.—Colonel John Bowden, O.B.E., M.Inst.C.E., M.I.Mech.E., Bushey, Herts; Andrew Custance Carr, V.D., M.I.Mech.E., M.I.E. (India), Past-President, Institution of Locomotive Engineers (Sir John Wolfe Barry and Partners), London, S.W.1; Geoffrey Lancaster Groves, B.Sc. (Eng.) (Lond.), A.C.G.I., M.Inst.C.E. (Mott, Hay and Anderson), London, S.W.1.

BRITISH STANDARD SPECIFICATIONS.

THE following specifications of engineering interest have been issued by the British Standards Institution. Copies are obtainable from the Publications Department of the Institution, 28, Victoria-street, London, S.W.1, and, unless otherwise stated, the price is 2*s.* net, or 2*s.* 3*d.* including postage.

A.R.P. Signs for Gas Cleansing Centres.—The Ministry of Home Security recently issued a circular giving approval to the use of location and direction signs to indicate public gas cleansing centres. The design of these signs is given in an addendum to Specification B.S./A.R.P. No. 32, and copies of this addendum (No. C.F. (A.R.P.) 8066) may be obtained gratis on application to the Institution, enclosing a stamped addressed envelope.

Devices for Detection of Incendiary Bombs.—A specification for devices of the heat-sensitive type for the detection of incendiary bombs (B.S./A.R.P. No. 53) was issued by the British Standards Institution some months ago. This has now been followed up by the issue of a new specification (B.S./A.R.P. No. 55) for detectors which indicate the presence of incendiary bombs when an electrical circuit is ruptured by impact. In these systems a bell or other alarm is operated as the result of a falling bomb causing the rupture of a special detector conductor which forms part of a closed electrical circuit. Systems of this type are stated to be primarily intended for installation in buildings such as dwelling-houses and small industrial or commercial premises, and if the specification is complied with the bomb will be detected immediately on arrival and before a fire has been started. The special detector conductor is passed backwards and forwards over the area to be protected and full directions for its spacing and arrangement are given. The mechanical properties of the conductor are specified in detail, as it is essential that the wire should break and not merely stretch when hit by a bomb. Thus plain soft copper wire is definitely unsuitable, but hard-drawn copper wire of No. 28 to 32 S.W.G. will meet the prescribed tests. As the system works on the closed-circuit principle, a relay must be used and its reliability is naturally a matter of particular importance. Details of suitable relays are given at some length in the specification, together with appropriate circuit diagrams. It is thought that the specification should appeal to the home constructor as well as to those who manufacture or install detector systems on a commercial scale. [Price 6*d.* net., or 8*d.* postage included.]

Silver Solder.—A revision of Specification No. 206 for silver solder, which was first published in April, 1924, has now been issued in order that a further silver solder, Grade C, might be included. Grades A and B are both of the ternary silver-copper-zinc alloy type, but the new solder is a quaternary alloy of silver, copper, zinc and cadmium which is now being increasingly used in industry. An appendix, giving the melting range of the three grades of solder now covered by the specification, is included for general information.

BOOKS RECEIVED.

"*Mechanical World*" *Monographs No.* 10. *Principles and Practice of Heat Treatment.* By J. WINNING. Manchester: Emmott and Company, Limited. [Price 2*s.* net.]

Reports of the Progress of Applied Chemistry. Issued by the Society of Chemical Industry. Volume XXV. 1940. London: Society of Chemical Industry, Clifton House, Euston-road, N.W.1.

Rensselaer Polytechnic Institute Bulletin: Catalogue Number, March, 1941. Troy, New York: Rensselaer Polytechnic Institute.

The Calculation and Design of Electrical Apparatus. By DR. W. WILSON. Third edition, revised. London: Chapman and Hall, Limited. [Price 10*s.* 6*d.* net.]

Electric Power Stations. Volume II. By T. H. CARR. London: Chapman and Hall, Limited. [Price 32*s.* net.]

Department of Scientific and Industrial Research. Building Research. Bulletin No. 13. *Calcium Sulphate Plasters.* Revised edition. By W. R. PIPPARD. London: H.M. Stationery Office. [Price 4*d.* net.]

PERSONAL.

SIR WILLIAM FRASER, C.B.E., has been elected chairman of the Anglo-Iranian Oil Company, Limited, in succession to the late LORD CADMAN.

MR. H. C. TURNER has been elected chairman of the North-Western Centre of the Institution of Electrical Engineers. He will succeed MR. B. A. G. CHURCHER, M.Sc., the present chairman, on October 1.

MR. M. C. HENDERSON has been elected President of the New Zealand Institution of Engineers.

MR. CHARLES DUKES has resigned from membership of the Industrial and Export Council and MR. H. HARRISON has been appointed to succeed him.

SIR WILLIAM BIRD, chairman of Messrs. The Staveley Coal and Iron Company, Limited, near Chesterfield, who will retire at the annual general meeting of the company in September, has announced that his successor is to be the present managing director, MR. D. N. TURNER. MR. H. H. BERRESFORD is to succeed Mr. Turner as managing director, and MR. T. A. MCKENNA, the present assistant commercial manager, is to become commercial manager.

MR. E. L. PAYTON, J.P., who has been deputy chairman of Messrs. The Austin Motor Company, Limited, Longbridge Works, Birmingham, since November, 1928, has been appointed chairman of the company in succession to the late LORD AUSTIN, K.B.E., LL.D.

MR. G. MILLS, divisional general manager, Scottish Area, London and North Eastern Railway, has been appointed divisional general manager, Southern Area, in succession to the late MR. H. H. MAULDIN. MR. R. J. M. INGLIS, engineer, Southern Area, has been appointed divisional general manager, Scottish Area, and MR. J. C. L. TRAIN, engineer, Scottish Area, is to be engineer, Southern Area.

MR. HAROLD HEATH, who has been associated for some years with the Rootes Group, has resigned his directorships of Messrs. Humber, Limited, Coventry, and its associated companies.

MR. F. C. HALL has been promoted to the position of principal assistant to the chief mechanical engineer, Great Western Railway. MR. W. N. PELLOW has been appointed locomotive-running superintendent and outdoor assistant to the chief mechanical engineer. Other appointments include that of MR. H. G. KERRY to the position of divisional locomotive superintendent, Old Oak Common, and MR. R. W. WOOLACOTT to that of assistant to the chief mechanical engineer.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel Trade.—No change in the state of the Scottish steel trade during the past week has been reported. Both shipbuilders and boilermakers are still exceptionally busy and are consuming a large tonnage of plates and sections, and there is a steady demand from constructional engineers for sectional material. In the black steel sheet trade there is still considerable business passing, but as the output has been kept on a large scale orders on hand have been brought up to date and makers are now able to promise fairly early delivery for any new business on offer. Steel scrap is not very plentiful, but every endeavour is being made to secure further supplies. Prices are unchanged and are as follow:—Boiler plates, 17*l.* 12*s.* 6*d.* per ton; ship plates, 16*l.* 3*s.* per ton; sections, 15*l.* 8*s.* per ton; medium plates, ¼ in. and thicker, rolled in sheet mills, 21*l.* 15*s.* per ton; black-steel sheets, No. 24 gauge, 22*l.* 15*s.* per ton; and galvanised corrugated sheets, No. 24 gauge, 26*l.* 2*s.* 6*d.* per ton, all for home delivery.

Malleable-Iron Trade.—Fairly satisfactory conditions are general in the malleable-iron trade of the West of Scotland, and the demand, although not of an urgent nature, is very steady. The easier tone which has been noted during the past week or two in the steel-bar re-rolling industry still prevails and early delivery can be promised for new orders. Most firms, however, have a fair amount of work on hand, but are prepared to undertake new business. The stocks of semies now held are ample for all requirements. The following are the current quotations:—Crown bars, 15*l.* 12*s.* 6*d.* per ton; No. 3 bars, 13*l.* 12*s.* 6*d.* per ton; No. 4 bars, 13*l.* 17*s.* 6*d.* per ton; and re-rolled steel bars, 17*l.* 15*s.* per ton, all for home delivery.

Scottish Pig-Iron Trade.—In the Scottish pig-iron trade a strong demand continues, as consumers are all in urgent need of supplies. The blast furnaces are being worked at their utmost capacity and the output of both hematite and basic iron particularly is being consumed rapidly. Foundry iron is still somewhat slow but deliveries represent a fair tonnage. Prices are steady and to-day's market quotations are as follow:—Hematite, 6*l.* 18*s.* 6*d.* per ton, and basic iron, 6*l.* 0*s.* 6*d.* per ton, both delivered at the steelworks; foundry iron, No. 1, 6*l.* 5*s.* 6*d.* per ton, and No. 3, 6*l.* 3*s.* per ton, both on trucks at makers' yards.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Welsh Coal Trade.—On the steam-coal market during the past week attention was again concentrated upon the drive for increased production. Mr. Ernest Bevin's wireless appeal for an extra 500,000 tons of coal a week, in which he gave a five-point programme that might enable it to be obtained, caused particular interest. It will be remembered that his five points were:—Managements to concentrate upon maximum immediate production; absenteeism to stop; men available in mining districts to be taken back into the industry immediately; men who have left the industry are to volunteer to return; and those employing ex-miners are to co-operate in releasing them. He indicated that the Government did not intend to release miners already called up for the Forces. The matter was under consideration by the South Wales Miners and it was understood that it would be discussed at a coalfield conference to be held on July 5. Regarding the statement that men were not to be released from the Forces, the general opinion was that increased production on the scale desired was not feasible without the release of these men. A dispute was threatened in the coalfield on the question of non-unionism. At a meeting of the executive of the Powell Duffryn Combine Committee of the Federation, a report was received from the Penallta Lodge which, it was stated in the official report, had received particular attention. The Lodge had decided to tender notices on July 14 next, and that loyal members of the Federation would refuse to work with non-unionists after the expiration of the notices. The Combine Committee decided to give full support to the Penallta Lodge. The report stated that they had noted the appeal for more coal, but were of the opinion that unless non-unionism was removed from the industry during the national emergency there could be no co-operation at the collieries on pit-production committees. It was decided to request the central executive of the Federation to discuss the non-unionist matter at the forthcoming coalfield conference. Conditions on the market again showed no material change. A brisk demand was circulating from both home and export markets, but little new business could be entertained as most salesmen had already disposed of almost the whole of their potential outputs for some time to come. The general tone was consequently very firmly maintained. Best large coals were moving off satisfactorily and the sized sorts remained difficult to secure for some time to come. The scarcity of the bituminous small grades remained acute and the occasional odd parcels that sellers had to offer for early delivery commanded high figures. The dry steam smalls, however, were in poor request and, with supplies plentiful, were dull. Cokes were active, but patent fuel was slow.

The Iron and Steel Trade.—Producers in the iron and steel and allied trades of South Wales and Monmouthshire were still kept busy. The demand for the various finished products was active, but order books generally were well filled for some time to come and new business was consequently checked.

WAR-TIME OPERATION OF ELECTRICITY UNDERTAKINGS.—The Electricity Commissioners announce developments and changes in the operation of electricity undertakings under war conditions in a memorandum dated June 20, 1941. Heading A of this memorandum states that the Minister of Labour and National Service has agreed to bring the Electricity Supply Industry within the field of the Essential Works (General Provisions) Order, 1941, and that the scheduling of electricity undertakings will be commenced forthwith. It is unnecessary for individual undertakers to make application for entry in the schedule. Heading B clarifies the conditions under which it is permissible to control the movement of electricians from one employer to another. In heading C, fire-prevention personnel during daylight hours is discussed and some relaxation of present conditions is allowed; for offices, showrooms, etc., the obtaining of immediate access by fire brigades and air-raid wardens, and the prompt reporting for duty of the fire-watchers concerned, is now permissible. For generating stations, etc., the personnel hitherto required may be reduced to 25 per cent. of the number required at night, subject to a minimum of three. Heading D relates to the recently-appointed factory liaison officers in connection with Home Guard personnel. Heading E gives the precautions necessary to prevent the accidental lighting-up of unobscured lamps, and Heading F relates to recent bulletins on air-raid precautions training. Any inquiries addressed to the Commissioners, Savoy-court, W.C.2, on matters dealt with in the memorandum should quote the appropriate heading as given, along with the pertinent reference number. This, for Heading A, is A/950/394/59K. For Headings B, C, D and E the same reference is used, though the figure 59K should be replaced by 59H, 139A, 112G and 55, respectively. The bulletins mentioned under Heading F can be obtained from H.M. Stationery Office, York House, Kingsway, W.C.2.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

General Situation.—The increased imports of American and Dominions iron and steel, together with the heavy local production, now cover the actual war-time requirements, and the usual customers are anticipating an expansion in the tonnage available for distribution for general industrial purposes. The congestion of orders at local works has been largely removed, and the pressure for delivery of several commodities has appreciably eased. The whole of the tonnage output continues to pass promptly into use and orders placed virtually absorb the prospective aggregate production for the third quarter of the year.

Cleveland Iron Trade.—The continued shortage of Cleveland pig gives rise to no difficulty as ample supplies of foundry iron are obtainable from other areas.

Basic Iron.—Producers of basic iron are maintaining an output which is quite equal to the heavy calls of their own steel works and occasional small quantities are being added to the light stocks.

Hematite.—The scarcity of hematite continues to necessitate the rationing of customers, but the demand is diminishing as the use of foundry and refined iron at engineering foundries expands and larger imports of overseas commodities, in which hematite is used, are coming to hand. There is little hope of any increase in the local make of hematite.

Blast-Furnace Coke.—Though Durham blast-furnace coke is plentiful and the consumption heavy, market transactions are on a very limited scale. Holders have a considerable tonnage for disposal, but are not inclined to add to their bookings until they have cleared a number of contract obligations and the requirements of local users are as well covered as is considered necessary.

Manufactured Iron and Steel.—Users of semi-finished iron and steel are taking full deliveries under running contracts, though they are carrying substantial stocks. Plants producing finished commodities are busily employed, priority being still given to specifications for shipbuilding requisites. The heavy outputs of tank and boiler plates, sheets, special alloy steels and railway material are passing into use as they become available and constructional steel is in good request.

Scrap.—The demand for iron and steel scrap is taxing the resources of the merchants. The exceptionally large deliveries do not fully meet the requirements of the consumers which are greatest in the case of heavy foundry iron and heavy steel.

SYDNEY ELECTRICITY UNDERTAKING.—During the year ending December 31, 1940, a total of 697,756,468 kWh was sold by the Electricity Undertaking of the Sydney County Council, Australia, as compared with 633,381,939 kWh in the previous twelve months. The average price charged to consumers decreased from 1·215*d.* per kWh in 1939 to 1·185*d.* in 1940.

STEEL FOR HAND TOOLS.—We are informed that all applications for authorisations for the purchase of steel for hand tools should henceforth be addressed to the Directorate of Hand Tools, The Cedars, Tettenhall, Wolverhampton. The definition of a hand tool for this purpose is "a tool operated by hand not requiring mechanical power to drive it."

THE CONTROL OF CHLORATES.—The Minister of Supply has issued the Control of Chlorates (No. 1) Order (S.R. & O. 1941, No. 827, price 1d.), which controls the purchases and sales of chlorates and all substances containing not less than 10 per cent. by weight of free chlorate. All inquiries and applications for licences should be made to the Chlorates Control, The Ministry of Supply, Raw Materials Department, Warwick.

INQUIRY INTO WHITEHAVEN COLLIERY ACCIDENT.—Under the powers conferred by section 83 of the Coal Mines Act, 1911, the Secretary for Mines has directed that a Formal Investigation shall be held into the causes and circumstances of the explosion which occurred in the William Pit, Whitehaven Colliery, Cumberland, on June 3. He has appointed Mr. F. H. Wynne, C.B.E., B.Sc., H.M. Chief Inspector of Mines, to be the Commissioner to hold the Investigation.

ALUMINIUM PRODUCING INDUSTRY IN AUSTRALIA.—News has been received from Australia that the Commonwealth Government has decided to produce aluminium from Australian bauxite of which there are large deposits in New South Wales, Queensland and Victoria. The ore is stated to be good commercial grade and a smelting plant is to be built at a cost of 1,500,000*l.* Rolling mills are already available and an extrusion plant is being constructed at the Sydney Works of the Australian Aluminium Company.

NOTICES OF MEETINGS.

IT is requested that particulars for insertion in this column shall reach the Editor not later than Tuesday morning in the week preceding the date of the meeting.

INSTITUTION OF ELECTRICAL ENGINEERS.—*South Midland Centre:* Monday, July 7, 6 p.m., The James Watt Memorial Institute, Great Charles-street, Birmingham. (i) Film: "Routine Maintenance of a 33 kV Oil Circuit Breaker," by Mr. G. F. Peirson. (ii) Informal Discussion on "Looking Forward," to be opened by Mr. R. H. Rawll. *Institution:* Thursday, July 10, 12.30 p.m., Savoy-place, Victoria-embankment, W.C.2. Ordinary meeting for the transaction of formal business only.

INSTITUTE OF PETROLEUM.—Tuesday, July 8, 5 p.m., The Institution of Mechanical Engineers, Storey's-gate, St. James's Park, Westminster, S.W.1. "Cable Impregnating Oils: Their Production and Characteristics," by Mr. J. C. Wood-Mallock.

IRON AND STEEL INSTITUTE.—Tuesday, July 8, 6.15 p.m., The Beaufort Hall, Mackworth Hotel, Swansea. Joint meeting with THE SWANSEA TECHNICAL COLLEGE METALLURGICAL SOCIETY. (i) "The Influence of Some Special Elements Upon the Strain-Ageing and Yield-Point Characteristics of Low-Carbon Steels," by Dr. C. A. Edwards, Mr. D. L. Phillips and Mr. H. N. Jones. (ii) "The Influence of Turbulence Upon the Structure and Properties of Steel Ingots," by Dr. L. Northcott.

INSTITUTION OF CIVIL ENGINEERS.—*Yorkshire Association:* Saturday, July 12, 2.30 p.m., The Hotel Metropole, King-street, Leeds. Ordinary Meeting. "The Lennox Road Refuse-Disposal Station," by Mr. W. S. Cameron. (Preceded by a luncheon at 1 p.m.)

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—Staggered holidays among steel-workers, engineers, and munition workers are less general in the Sheffield district than was anticipated three months ago. Indications are that about 60 per cent. of the workers in both the heavy and light industries will be on holiday during August bank holiday week or the preceding week. Sheffield is concerned, of course, not only with engineering, but also with steel melting, and it would be unwise to have staggered holidays for steel melters. From the economical point of view it is better for a firm to close down for one week so that urgent maintenance work can be carried out, and the majority of firms in this area are adopting this policy. That exceptional progress is being made by all branches of the steel-manipulating and engineering trades is indicated by the great increase in steel output during the past six months. Plans are under consideration for the laying down of more electric furnaces of both the arc and high-frequency types which are used in the production of high-efficiency steels. The call for raw and semi-finished materials shows further expansion. Both basic and acid materials are in strong demand, and steelmaking alloys find a ready sale. Among the lines in special request are ferro-molybdenum, ferro-manganese, ferro-vanadium, ferro-silicon, ferro-chrome, tungsten, and cobalt. Encouraging reports are to hand from the heavy machinery and engineering branches. Structural-steel makers are busily employed, not only in providing steel supports for A.R.P. purposes, but also in connection with building developments for the Services and for factory extensions in various parts of the country. More steel is being used for supporting roofs in mines as a result of the scarcity of wooden pit props. The trade in railway rolling-stock requirements shows a further increase, and good business is being done in wheels, axles, springs, tyres and buffers; spring steel is an exceptionally brisk line. The inland demand for grinding and crushing plant has been well maintained, and the market in cement- and concrete-making plant has many bright features. Coal-cutting machines and steel tubs are in demand, which is likely to increase during the next few weeks when efforts to increase coal production get into full swing. Makers of agricultural machinery and parts are busy.

South Yorkshire Coal Trade.—Export business is still very restricted. The inland position is stronger and industrial coal is in heavy demand. Many works are building up stocks to offset a possible shortage of supplies during the winter. The call for smalls and slacks is better than it was three months ago, and locomotive coal is moving in larger quantities. The house coal market is affected by seasonal influences, but the coke position shows little change.

UNITED STATES OIL INDUSTRY.—The production of crude oil in the United States, in the last week of May, averaged 3,772,850 barrels a day, against 3,784,450 barrels in the preceding week.

THE "AIRGRAPH" LETTER SERVICE.

(For Description, see Page 7.)

FIG. 1. INSPECTION OF MINIATURE FILM.

FIG. 2. ENLARGING MACHINE.

FIG. 3. DEVELOPING AND FIXING MACHINE FOR LETTERS.

FIG. 4. DRYING DRUM FOR LETTERS.

ENGINEERING.

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TIME FOR RECEIPT OF ADVERTISEMENTS.

Classified advertisements intended for insertion in the current week's issue must be delivered not later than first post on Wednesday. Alterations to standing advertisements must be received at least 10 days previous to the day of publication. Passed proofs must be in our hands by Saturday morning, otherwise they will be taken as correct. The Proprietors will not hold themselves responsible for blocks left in their possession for more than two years.

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For the duration of hostilities, the Editorial and Publishing business of this Journal is being conducted from 18 and 20, Compton Road, Hayes, Middlesex. The Telephone Number of the Editorial Department is Hayes 1730, and that of the Publishing Department, Hayes 1723. The Bedford Street Offices are open on Fridays only, between 10 a.m. and 5 p.m., for the distribution of the current issue and for retail sales.

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ENGINEERING

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LONDON RECONSTRUCTION.

IT is not difficult to foresee that there will be long and possibly acrimonious discussions regarding the reconstruction of London as soon as the cessation of hostilities offers the opportunity to plan this vast undertaking with reasonable certainty that the plan may not have to be re-cast as the result of further raids. Already there are indications that Londoners themselves are grouping into two opposing camps, those supporting Lord Quickswood in his plea that the old courts and often tortuous ways should be preserved as far as it may be feasible to do so, and those who would seize the opportunity to sweep away enough of the buildings that remain in order to construct a new and strange Metropolis of wide, straight streets, mighty self-contained blocks of offices and flats, and zones of various kinds, devised *ad hoc* to promote the greatest efficiency in everything that Londoners and their visitors may have to undertake in their pursuit of business or pleasure. What may be the outcome of this conflict of ideals, we are not prepared to prophesy; but it is safe to say that the fruition of whatever plan is eventually adopted is unlikely to be attained in the lifetime of any of its sponsors.

Meanwhile, it is good commonsense to remember and apply the broad principle that it is cheaper to experiment on the drawing board than on the job; and, until the time comes for the appointed official body to tackle the problem in earnest, there is everything to be said for the fullest discussion, among all grades of those who will be affected by the results of their deliberations, of all the possible forms that the reconstruction may take. The problem is unique in the history of mankind. Other cities have been devastated—many of them far more thoroughly than the German raiders have yet dealt with London—but none of them has occupied a comparable position, either in size, in importance, or in the multitude of the outside interests that are concerned in the decisions to be taken. Several of these considerations, so liable to be overlooked by the uninstructed critic, but so crucial in fact, were brought out during the discussion on the paper on "City of London Reconstruction," which Mr. S. Bylander and Mr. H. Boddington jointly presented at a meeting of the Institution of Structural Engineers, held in London on June 26.

The paper itself was comprehensive in scope and outlined a scheme whereby the collaboration of engineer and architect, to a degree not commonly attained hitherto, might result in the construction of a city more suitably designed for the purposes of trade, traffic and general convenience than the haphazard growth of past centuries could ever become by any process of piecemeal modification. This vision naturally involved some fairly detailed planning of buildings, streets, and rail access, and the paper contained thoughtful contributions under all these heads. No attempt was made to plan particular areas with reference to their existing limitations, their character or the historic or otherwise important buildings which might be regarded as worthy of retention in any new scheme; and it was noteworthy that, in their proposals for ring roads and for a revised railway layout, the authors endeavoured to locate their new routes in districts which, by common consent, would be improved rather than otherwise by large-scale demolitions.

A primary need, the authors pointed out, was to reorganise the business of London in sufficient volume to ensure recovery of Britain's former commercial supremacy, and for this reason the first reconstructed section of the City should be ready for occupation not more than twelve months after the war. The full development of the reconstruction scheme, they continued, must provide for arterial roads round London, with a loop road round the City; facilities for rapid transit of passengers and goods across London, and for higher buildings than are permitted at present. Plans must be included for a central passenger station, connected by tunnels with the present main-line railways, to and from which the trains would be drawn by electric locomotives. No satisfactory transport system, they considered, could be obtained merely by widening streets, and they advocated overhead motorways to connect the railway stations, docks, and important supply centres, with links as necessary to the main arterial roads outside the London area. If an airport should be considered necessary in London itself, one could be provided by roofing over the railway yards at St. Pancras and King's Cross. State control and leadership, with the requisite authority vested in a non-political commission, was advocated for the purpose of solving the immediate problems after the war, but it was fundamental to the scheme that private responsibility should be restored as soon as possible, to give full opportunity for business and cultural development.

We do not propose to consider the suggested designs for blocks of buildings, or the arrangements proposed for financing and controlling the work of rebuilding the City, or the broad scheme whereby the fullest co-operation between architect and engineer might be achieved; but rather to concentrate on the primary questions of transport, the solution of which must decide the success or failure of any replanning project. The paper afforded ample evidence that the authors had devoted careful attention to this problem and fully realised its fundamental importance; yet there were practical points raised in the discussion which indicated, even more clearly than did the paper itself, how close must be the collaboration between all the interests affected if a really workable combined system is to be assured.

Their proposal was that a "London Central" station for passenger traffic should be constructed in the Soho district, between Oxford-street and Piccadilly Circus, with direct rail connection to seven of the main-line termini existing at present. Links would be provided, also, with the four tube railways now serving this district and possibly with the District and Metropolitan systems as well. It was assumed that the present main-line railways would eventually be electrified; but, until that was done, the cross-London trains would be hauled by electric locomotives through tunnels passing beneath the existing termini and out to "approach stations," about 15 miles from the central point, where the exchange of locomotives would take place. This railway scheme requires to be considered in conjunction with the proposed system of main and auxiliary roadways, which visualised trunk roads running east and west, with cross roads running north and south over the Thames. The positions of the cross roads would be governed by those of existing or proposed bridges and tunnels. To

facilitate rapid movement of traffic, crossings would be arranged on the clover-leaf principle, allowing traffic in all directions to flow continuously. The main through routes, the authors proposed, should be elevated motorways, wide enough to carry three lines of traffic in each direction, and linked by ramps at appropriate intervals with parallel ground-level streets, separated from the elevated roads by blocks of buildings. The buildings would have direct access to the elevated roads as well as to the ground-level roads, and the space under the elevated roadway would afford ample garage accommodation. The whole paper, it may be mentioned, clearly implied a great increase in the volume of road traffic, though no indication was given of the respective shares expected to be taken by railways, tubes, public-service road vehicles, commercial vehicles and private cars in transporting the normal passenger and goods traffic of Greater London.

The general plan, which bore some resemblance in parts to the proposals of the Bressey Report, comprised a loop line at a distance of two to three miles from the centre of London, linking Eastern-avenue and Western-avenue on the north, and passing through Fulham, Clapham, Camberwell and Greenwich to the south. River crossings would be made by a double-deck bridge at Battersea and via the Blackwall Tunnel. The capital expenditure for the complete scheme, as the authors truly observed, would be enormous, as it would include the requisitioning of land along the motorway to a total width of some 600 ft. in addition to he cost of the actual constructive works; it would have to be provided out of national funds, on the principle that facilities for transport and business would create wealth, and thus ultimate revenue.

Undoubtedly, the scheme has been well thought out; but, as mentioned above, it failed apparently to take into due consideration certain physical facts of some importance. The President of the Institution, Mr. W. K. Wallace, as a railway man of experience in civil-engineering difficulties and railway traffic operation, pointed out that the complicated systems of tubes, mains, sewers, etc., already existing in London made it almost impossible to lay out suitable lines for any more tunnels; and that at least two more tracks than the authors had legislated for would be needed in the connections to the proposed London Central station. It would not be practicable to run long-distance trains through London from north to south and on to the coast; when they had discharged their London-bound passengers, they would require to be transferred to the carriage sidings for cleaning, for restocking restaurant cars, etc. Moreover, the heavy traffic in parcels sent by passenger train, which was still increasing at a considerable rate, required its own handling facilities and the services of fleets of delivery vans, which also must be accommodated in or near the station. All things considered, he did not regard the London Central station proposal as desirable, an opinion in which others concurred.

There is little doubt that the ring road or loopway round London will form part of the eventual re-organisation, as it is the logical development of work that is already in hand and largely completed. Extensive tunnelling we do not regard as generally practicable, for the same reasons which caused Mr. Wallace to object to this feature of the central station scheme. The plan for building blocks of offices and warehouses quickly and economically by the development of designs that are standard in the main essentials is obviously feasible, and might well be adopted on the general lines suggested; though not, we hope, to the height of 200 ft., indicated in the paper. Regarding, however, the probable effect upon the amenities of London of a series of elevated motorways, whether or not they are flanked and hidden from view by rows of tall buildings, we incline rather to the opinion, expressed by Mr. W. H. Ansell in his address to the Royal Society of Arts,* that South London in particular has suffered more than enough from the sectionalising influence of railway embankments and that such structures should rather be abolished wherever possible than be increased in number.

* See ENGINEERING, vol. 151, page 232 (1941).

RAW MATERIALS.

WHEN, in the early years of the Nazi regime, Mr. Winston Churchill began to warn the British Government and people that Germany was subtly rearming and, in particular, was actively engaged in building up a strong air force in defiance of the provisions of the Versailles Treaty, many inclined to wonder on what secret information his very positive declarations were based; if, indeed, they had any factual basis at all, and were not merely personal deductions from his knowledge and experience of the character of German political and military leadership. Not until long afterwards was it revealed that they were founded, in fact, upon a careful analysis of the imports into Germany of magnesium and other special metals, essential to the production of munitions of war and especially of modern military aircraft. In the period immediately before the war, and since active hostilities began, comparative studies of this kind have been developed to a high standard of efficiency, by the Ministry of Economic Warfare, as a necessary part of the organisation of blockade; but they have a peace-time value also, and are certain to have an important influence on the plans for the settlement and economic regeneration of Europe after the war.

While the principal clamour for self-sufficiency as a national right has been raised by the Axis Powers, and obviously with aggressive military intentions rather than from reasons of genuine economic difficulty, the long period of international trade depression had forced many other nations to examine closely the extent of their own natural and developed resources and of possible alternative sources of supply from which they might obtain essential raw materials on the most favourable terms. There was no vestige of truth in the inspired declarations emanating from Germany, Italy and Japan, in particular, that the fact that so many of the principal sources were in the British Empire or under British control constituted in some way a menace to their own industrial security; in many cases, indeed, they could have bought in other markets or developed their own concessions elsewhere, had they chosen to do so. It is to be expected, however, that such arguments will be resuscitated in the future, in the endeavour to secure special consideration that may mitigate the after-effects of war; and, therefore, it behoves the British and American peoples to inform themselves in advance of the true position of raw-material supplies and production.

For a number of years, the complex undertaking of collating the mass of statistical information available throughout the world, regarding the actual and potential production and reserves of raw materials and foodstuffs, has been a major activity of the Royal Institute of International Affairs, and authoritative surveys have been published in the series of Information Department Papers issued by the Institute. The latest of these, No. 18B, deals with "World Production of Raw Materials,"* and is a development of an earlier publication, No. 18A, which was issued in November, 1939. That Paper, as is explained in the introduction to the present pamphlet, was mainly a study of how far the claims made by the Axis Powers for colonial expansion, if granted, would be effective in solving their economic difficulties. Since the outbreak of war, and especially since Germany has succeeded in over-running Europe, the position has been radically altered by the growing demand for those supplies which are essential for war purposes, and by the restrictions imposed by the British blockade and by difficulties of transport. The whole of Europe is now virtually a single economic unit, both for production and consumption; while the Dutch and Belgian colonies, and the colonial possessions now controlled by Free France, are cut off from their normal home markets and must find other outlets for their commerce. At the same time, the internal trade of the British Empire is largely dictated by purely military considerations, as is British trade with the United States; and yet, in spite of the productive disorganisation resulting from nation-wide preoccupation with munitions supply, Britain is more than ever under the necessity of retaining and, if possible, expanding the normal commercial intercourse with non-belligerent countries, especially in South America.

* "World Production of Raw Materials." London: The Royal Institute of International Affairs. [Price 2s. 6d. net.]

The information given in the pamphlet is in tabular form, and is grouped in the general categories of metals, other minerals, textile fibres and rubber, vegetable oil-seeds and nuts, and foodstuffs (which, incidentally, includes tobacco, of which more than 3½ million tons was produced during 1939-40.) The accompanying notes relate principally to the war-time uses of the various commodities and, taken together, give an informative survey of the relative economic positions of the Axis and the Allies, indicating clearly how much more important are some of the minerals, in particular, than the actual quantities produced might appear at first sight to imply. For example, Germany seems unlikely to suffer any shortage of iron-ore supplies, even without the contribution represented by the exploitation of internal reserves of low-grade ores, but has to contend with a serious lack of several of the materials essential to the production of special steels. Something like 95 per cent. of the world's manganese is used in steel-making; but Germany's own production is only about 8 per cent. of the total, and Italy can add to this only 0·4 per cent. Russia, on the other hand, produced over 41 per cent. of the world total in 1938, so that a successful campaign against the U.S.S.R. would materially aid Germany's steel position if an appreciable proportion of this output could be diverted to the Reich. Russia also has substantial supplies of chromium, and is the world's largest producer of magnesite—both important in steel manufacture; and could probably solve Germany's difficulties in obtaining mercury and platinum, if control of those resources could be established. Having absorbed Austria, Germany has now ample supplies of magnesium; and can draw bauxite, the main commercial source of aluminium, from Italy, France, Hungary, Rumania, Yugoslavia, and Greece, which together produced over 50 per cent. of the world's output in 1938.

Petroleum and petroleum products have been commonly recognised from the outset as crucial factors in the war effort of both sides, and many have been the confident assurances that Germany must shortly collapse for lack of these essential commodities. The survey provided by the Royal Institute appears to indicate that there was reasonable justification for this belief, if the statistics are only approximately accurate. World production of crude petroleum is of the order of 300 million tons a year, of which more than three-quarters is produced and refined in the western hemisphere. Much of the production, however, is consumed in the countries of origin, only about 80 million tons changing hands in the way of international trade. The total European output, excluding that of Russia, was about 7½ million tons; only a quarter of the consumption for inland purposes (that is, other than bunker fuel for seagoing vessels). Germany's production of oil from lignite and coal may be as much as 3 million tons, apart from that of additional plants which may have been constructed since the war began. To this must be added about half a million tons of benzol and a combined total of perhaps as much again of industrial alcohol and shale oil. It is evident, therefore, that the oil position of the Reich must be increasingly serious, and that the heavy demands made by the offensive against Russia are likely to tax the available resources severely if the campaign is at all prolonged. Hitherto, in spite of occasional large-scale air activity and the successive thrusts into Norway, the Low Countries, France and Greece, it is probable that consumption has been within the limits of a carefully husbanded average output. A long war, however, on a front of 1,500 miles, German war economics cannot afford to contemplate; and, in view of the location of the Russian wells, it is difficult to see how even a victory over Russia can produce a petroleum dividend of any magnitude in time to counteract decisively the combined effort of the British Empire and the United States.

NOTES.

CABINET CHANGES.

AN important announcement regarding changes in some of the higher Cabinet posts was issued from No. 10, Downing-street on Sunday night, June 29. This stated that H.M. The King had been pleased to approve of the appointment of the Right Hon. Lord Beaverbrook as Minister of Supply; that the Right Hon. Sir Andrew Rae Duncan, G.B.E., M.P., was to be President of the Board of Trade, while continuing to act as chairman of the Import Executive; and that Mr. Oliver Lyttelton was vacating the office of President of the Board of Trade on being appointed to special duties abroad. The announcement further stated that Lord Beaverbrook would remain a member of the War Cabinet and that his appointment as Minister of Supply brought to an end the special arrangement whereby he, as Minister of State, acted as deputy chairman of the Defence Committee (Supply) and as referee on priority questions. These questions, it was pointed out, would henceforth be handled within the organisation of the office of the Minister of Defence or of the Production Executive, of which latter, Mr. Bevin would continue to act as chairman. The concluding paragraph of the announcement dealt with the appointment of the Right Hon. J. J. Llewellin, C.B.E., M.C., M.P., and the Right Hon. Sir Arthur Salter, K.C.B., M.P., hitherto Parliamentary Secretaries to the Ministry of Transport and Ministry of Shipping, respectively, to the position of Joint Parliamentary Secretaries to the Ministry of War Transport.

BIRTHDAY HONOURS LIST.

A second section of the King's Birthday Honours List relating to awards to members of the three Services, was published on July 1. Among the recipients of Companionships of the Order of the Bath are eight officers of the Royal Navy, two belonging to the Engineering Branch, namely, Engineer Rear-Admirals H. L. Harvey and H. A. Sheridan. Another recipient of the C.B. is Major-General R. H. Dewing, D.S.O., M.C., late of the Royal Engineers. Engineer Captain G. L. Annett, Head of the Engineering Branch, Royal Indian Navy, receives a Companionship of the Order of the Indian Empire; and Engineer Rear-Admiral G. Morgan, Col. (Temp. Brig.) W. H. Oxley, M.C., late R.E., Col. (Temp. Brig.) W. E. C. Pickthall, O.B.E., R.A.O.C., Lt.-Col. (Temp. Brig.) W. C. H. Prichard, D.S.O., R.E., and Col. (Temp. Brig.) H. E. Roome, M.C., late R.E., become Commanders of the Order of the British Empire. The list of the new Officers of the Order of the British Empire includes the names of Engineer Captains E. C. Green, D.S.O., R.N. (Retd.) and A. E. Waters, R.N. (Retd.); Acting Engineer Captain J. W. Wishart, Royal Australian Navy; Engineer Commanders J. T. Belfield, R.N. (Retd.), and J. V. Thompson, R.N.R.; Majors (Temp. Lt.-Cols.) E. F. E. Armstrong, R.E., and G. A. Bloom, R.E.; Lt.-Col. A. R. Brown, R.A.O.C.; Lt.-Col. (Temp. Col. and Acting Brig.) N. C. D. Brownjohn, M.C., R.E.; Major (Temp. Lt.-Col. and Ordnance Mechanical Engineer 1st Class) J. A. E. Burls, A.M.I.Mech.E., R.A.O.C.; Lt.-Col. (Temp. Col.) D. Campion, R.E.; Lt.-Col. (Temp. Col.) B. Pennefather-Evans, M.C., Indian Army Ordnance Corps; Lt.-Col. R. H. S. Hounsell, M.B.E., R.E.; Lt.-Col. H. T. S. King, R.E.; Major B. H. S. Lloyd, R.E.; Major (Temp. Lt.-Col.) J. W. MacKillop, R.A.O.C.; Lt.-Col. (local Col. and Ordnance Officer 1st Class) J. F. F. Oakeshott, R.A.O.C.; Lt.-Col. (Acting Col.) H. de L. Panet, R.E.; Major (Temp. Lt.-Col.) T. J. P. Price, R.E., and Lt.-Col. and Ordnance Officer 2nd Class J. E. Ruddock, R.A.O.C. A subsequent announcement stated that Mr. Lyttelton was appointed Minister of State and would represent the War Cabinet in the Middle East.

THE ASSOCIATION OF CONSULTING ENGINEERS.

The report of the committee of the Association of Consulting Engineers, for the year ended April 30, 1941, indicates that the Association has been successful in maintaining its various activities, in spite of unavoidable complications introduced by the war. The membership, at the close of the official year, stood at 153, of whom 140 ranked as "effective members," nine were serving with the Forces or were otherwise engaged exclusively on war work, and four were "non-practising members," elected to that grade under one of the amendments made to the Articles of Association, referred to in last year's report. The committee observe that it was especially fitting that the first member to be so elected should be Mr. A. H. Dykes, who was closely connected with the foundation of the Association in 1913 and, for 23 years, was honorary secretary. Mr. S. C. Lewis, who has also retired from practice, held the office of honorary treasurer for more than 14 years. He relinquished it on December 31, 1940, and has been succeeded by Dr. W. L. Lowe-Brown. At their first meeting, held on June 3, 1940, the committee elected Mr. E. J. Buckton, B.Sc., senior partner in Messrs. Rendel, Palmer and Tritton, to be chairman for the year. It is noted that Mr. Buckton's active steps to bring to the notice of the Government the desirability, in the public interest, of making the fullest use of consulting engineers in connection with the national war effort, appear now to be bearing fruit. For the purpose of carrying out large works, several groups of consulting engineers have been formed, and these have utilised the services of other consultants as specialists. On numerous occasions, it is stated, the names of all members of the Association, qualified in special branches, have been communicated to Government departments in response to inquiries regarding contemplated or specific works. A special scale of fees has been agreed with the Ministry of Works and Buildings in connection with the provision of shelter accommodation in public buildings. It is emphasised, however, that this concurrence is a war measure, and that the scale is not considered to be applicable to normal engineering works. Mr. S. R. Raffety and Mr. Ranald J. Harvey continue to act as honorary secretaries of the Association, the office of which is still at 241, Abbey House, Victoria-street, Westminster, S.W.1; but the appointment of a whole-time secretary (Mr. Edward Baynes, C.B.E.), having raised the question of the adequacy of the office accommodation, steps are being taken to obtain more suitable offices.

ROAD CASUALTIES.

The return, published last week by the Director-General of War Transport, of "the numbers of persons reported to have died in Great Britain during the month of May, 1941, as a result of road accidents" can only be regarded as a disturbing document; for, whether on roads subject to speed limit or not, and whether during hours of darkness or "other hours," the numbers show an increase in every case, and almost in every category of persons, over the corresponding figures for May, 1940. The principal totals are as given below, the figures for May, 1940, being shown in brackets after each item. During hours of darkness, in speed-limited areas, there were 79 (68) persons killed, and on roads not subject to speed limit, 71 (62); during other hours, 384 (211) and 167 (108), respectively. The totals for the month, therefore, are 701 for 1941, as against 449 in 1940. The categories of persons are pedestrians (i) under 15 years of age and (ii) 15 and over; drivers of mechanically-propelled vehicles other than motor cycles; motor cyclists; pillion passengers; pedal cyclists (i) under 15 and (ii) 15 and over; and "other persons." The numbers of pedestrians of 15 or over who lost their lives show a reduction, during hours of darkness, from 77 to 49; and drivers of motor vehicles other than motor cycles, during "other hours," from 18 to 16—a change so slight as to have little value for purposes of argument. Otherwise, every category shows an increase. It is difficult, however, to draw any definite conclusion from the return regarding the directions in which action should be taken to reduce this heavy toll permanently. War-time lighting restrictions can hardly be held responsible; and the recent inquiry by the War Office into the number of accidents in which Army vehicles were concerned appears to absolve military transport from the suspicion of being involved in more than a strictly proportionate share in the total. The statistics available to the Ministry of War Transport, of course, are much more detailed than is indicated in the brief statement from which we have quoted, and it would seem that some better guidance might be afforded to the public, in the task of assessing the value of the published figures, if some of this additional information could be given equal publicity. For example, the number of cars on the road, and the approximate mileage that they are likely to have covered in a given month (which could be computed with sufficient accuracy from the figures for petrol supplied) would enable the casualties to be viewed in truer perspective. A feature of war-time motoring, too, is the obviously higher average of passengers per vehicle, as a result of restrictions in public transport and the practice of giving "lifts" to other wayfarers. This practice may affect the totals or it may not; in either case, some indication might assist in elucidating the general position. That it may not, in fact, have any real bearing on the increased road casualties is suggested by the recent issue by the Ministry of regulations to the effect that, "for the duration of the war, it shall be no offence to give a casual free lift to members of H.M. Forces in uniform in a vehicle being otherwise lawfully used under a Limited Trade Licence." That it should be necessary to issue a special authorisation like this, with the ponderous title of The Road Vehicles (Registration and Licensing) (Amendment) Provisional Regulations, 1941, to enable a lorry-driver to give a soldier a lift, suggests that one thing that is the matter with the present road position is an excess of official regulation. Colonel Moore-Brabazon was "translated" (to use his own term) from the Ministry of Transport before he had time to grapple with the increasing tangle of its road legislation. If, when the war is over, he is able to return to it and to induce sufficiently influential support of his vision of motoring as an agreed general necessity, not merely a selfish pleasure, we shall hope to see some simplification of what is now the very complicated business of driving along British roads. It seems not impossible that simpler motoring may also prove to be safer.

THE HARBOUR OF WELLINGTON, NEW ZEALAND.

The interference caused by the war in normal overseas trading is well illustrated by the report of the Harbour Board of Wellington, New Zealand, for the year ended September 30, 1940, the trade of the port having shown a considerable decrease in the tonnage of both shipping and cargoes handled, in spite of the inclusion of Government transports in the totals of shipping entering and clearing during the year. The cargo handled amounted to 2,078,725 tons, a decrease of 12 per cent. by comparison with the previous year; and the shipping arrivals, which totalled 3,801,034 tons, represented a decrease of 6·2 per cent. In imports alone, which were 1,140,934 tons, there was a decline of 234,824 tons, or 17 per cent.; but, while this percentage applied also to British and foreign imports, those from Australia showed a fall of 21·8 per cent. Transhipments, however, showed increases of 19·8 per cent. in cargo for British and foreign ports and 28 per cent. in cargo for Australian ports. Exports to British and foreign ports increased by 19·8 per cent., although outward cargo, taken as a whole, declined by 78,911 tons, or 12·9 per cent. The export of cheese rose by more than 17 per cent., but that of butter fell by 7 per cent. The tonnage of oils in bulk pumped ashore was reduced by 15·4 per cent. and of outward bulk oil, by 21·6 per cent., but oil transhipments increased by 36·8 per cent. During the year, 20 per cent. of New Zealand's exports and 35 per cent. of the total imports passed through the port. A point which may have some bearing on allegations of congestion in British ports is mentioned in the address of the chairman of the Board (Mr. W. L. Fitzherbert); namely, delay in clearing cargo because of the late arrival of shipping documents from overseas. The annual report of the chief engineer to the Board (Mr. E. D. Cachemaille), which is included with the general statement of the year's working, shows that the floating dock was used, during the year, by 31 vessels, in addition to six dockings of the Board's own floating plant. The earnings of the dock showed a satisfactory increase.

LETTERS TO THE EDITOR.

SOME TEMPERATURE EFFECTS WITH COMPRESSED AIR.

TO THE EDITOR OF ENGINEERING.

SIR,—The article on this subject on page 444 of your issue of June 6 brought to the writer's recollection some tests which were made about 20 years ago. An air compressor of the, then, latest Reavell "quadruplex" design was undergoing efficiency tests, carried out by the late Captain H. Riall Sankey. To obtain the free air delivered (F.A.D.) of the compressor, arrangements were made so that both receiver pump-up tests and low-pressure parabolic nozzle tests could be carried out. It was found that the receiver tests consistently gave better results, from recollection about 3 or 4 per cent. It was assumed that the receiver test results were too high and that this was almost certainly due to difficulty in correctly measuring the temperature of the air inside the receiver at the end of the pump-up. Every effort was made to arrange conditions so that the temperature could be accurately read, even to the extent of installing a large cooler between the regulating valve on the compressor delivery and the inlet to the receiver. This had the effect of steadying the temperature of the air passing into the receiver, but had no appreciable effect on the F.A.D. obtained, which was still higher than given by the nozzle.

At this point it was suggested that the air entering the receiver during the test was acting as a piston in compressing the air already within the vessel, and that every increment of pressure caused an increment of heat, so that the temperature rose within the receiver all the time it was being charged. Looked at in this way, it is clear that the original air in the receiver was compressed through the full range of pressure, and each quantum of air entering the receiver was also compressed from the pressure at which it entered up to the final pressure; so that, at the end of the charge, which only took about one minute, an evanescent temperature was reached which could not be read by a thermometer. The difficulty was overcome by closing the receiver inlet valve at the end of the charge and waiting for the temperature within to fall to atmospheric temperature. This took between 10 and 15 minutes with a receiver having a capacity of approximately 100 cub. ft. As the temperature dropped in the receiver, so the pressure dropped, and the volume of free air charged into the receiver was calculated from the minimum pressure read at the end of cooling. The F.A.D. so obtained agreed within ½ per cent. with the nozzle results.

These tests contributed their part in speeding the work carried out, first of all by the Institution of Civil Engineers, and afterwards, at the request of the British Compressed Air Society, by the British Standards Institution, which resulted in the production of British Standard No. 726, standardising nozzle tests for obtaining the F.A.D. of an air compressor. These standard nozzle tests have now superseded receiver tests, which, unless they are very carefully carried out, can give misleading results.

Yours faithfully,
R. L. QUERTIER.

Reavell and Company Limited,
17, Victoria-street, Westminster, S.W.1.
June 26, 1941.

TO THE EDITOR OF ENGINEERING.

SIR,—The article in your issue of June 6, "Some Temperature Effects with Compressed Air," by Mr. A. L. Egan, requires some comments. Two processes are dealt with, namely, charging a receiver with compressed air, and blowing it down to atmosphere. The conclusion arrived at is that these processes are accompanied by considerable temperature changes in the receivers.

One of the fundamental laws applying here is that the energy of a perfect gas is only a function of the temperature. In neither of the two processes is there any heat introduced from outside nor is any heat taken out. In this case, the law expresses the relation between external work and temperature. When filling a receiver with compressed air no external work is done to the air; therefore, no temperature rise is taking place. Again, when a receiver containing compressed air is blown down to atmosphere, no external work is done by the air, the result being that there is no temperature drop.

For the purpose of this argument the influence of the Joule-Thomson effect can be ignored; also the fact that, behind a valve, local cooling will take place which may cause some heat to pass into the system. Broadly speaking, both processes take place without changes in temperatures, or perhaps a change of a few degrees, where some hundreds of degrees are mentioned. Apart from theoretical reasons, every day experience in compressor testing work shows that the phenomena claimed do not happen.

Yours faithfully,
C. RUEGG.

Bixley-road,
Ipswich, Suffolk.
June 24, 1941.

OBITUARY.

MR. C. P. SANDBERG, C.B.E.

THE death of Mr. Christer Peter Sandberg, which occurred on June 26 at his home at Edenbridge, Kent, removes a well-known figure from engineering circles in London. Mr. Sandberg, who, since 1913, had been senior partner in the firm of Messrs. Sandberg, founded by his father, the late Mr. C. P. Sandberg in 1868, was born on August 11, 1876. He received his general and scientific education at Dulwich College, at the Crystal Palace School of Engineering and at University College, London. In 1894 he commenced a pupilage of four years, first under Mr. W. Kirtley and afterwards under his father, whose firm was mainly concerned with measures for improving the soundness and wearing capacity of steel rails. To this work Mr. Sandberg's first important contribution was his patent, taken out in 1914, for the heat treatment of rails by the now well-known Sandberg Sorbitic process. Further work by Mr. Sandberg and his two brothers, aided by their metallurgical staff, led to the introduction, in 1928, of the Sandberg oven treatment for controlling the cooling of rails, after manufacture, through a critical range of temperature, to correct any tendency to internal fissuring. This treatment also made possible the introduction of more drastic sorbitising treatment of the rail head, giving a still harder-wearing and tougher rail, and to this process the name of Regulated Sorbitic treatment was given.

It is interesting to recall that, during the war of 1914–18, the application of the sorbitic treatment to shell forgings restored to serviceability large quantities which had been rejected on account of their low yield value, and that the process was presented by Mr. Sandberg to the Government free of all royalties. Another war development was the sorbitic treatment of tramway rails *in situ* to overcome difficulties of replacement. We understand that some 700 miles of tramway track were treated in this way. It is also worthy of note, as indicating Mr. Sandberg's wide range of interests, that the operations whereby the cargo of gold was recovered from the S.S. Egypt, which sank off Ushant in 1922, were carried to a successful conclusion largely owing to his determination and far-sightedness. In addition to his inspection work for certain British railways, Mr. Sandberg acted as consulting and inspecting engineer for the Chinese Government Railways, the Siamese State Railways and various Colonial railways. For his services during the war of 1914–18 he was made a Commander of the Order of the British Empire in 1920. He became an associate member of the Institution of Civil Engineers in 1902 and was transferred to the class of member in 1918. He was elected a member of the Iron and Steel Institute in 1898. Mr. Sandberg was made a Commander of the Chinese Order of Chia Ho (3rd Class) in 1922 and a Commander of the Siamese Order of the White Elephant in 1925.

OCEAN AIR TRANSPORT.*

By J. T. TRIPPE.

THAT this distinguished gathering has convened here to-day, amid the chaos of a war-torn world, for a lecture on civil aeronautics is indeed a singular expression of the true spirit of our profession. It is, I think, graphic proof of the fact that all of us in aviation are looking forward to the day when the aeroplane can lay aside its duties of destruction and once more assume its truly great role as a constructive force in world civilisation. I am, therefore, particularly sensible of the privilege of delivering the 29th Wilbur Wright Memorial Lecture. We in America feel that an invitation to address you, the parent body of the aeronautical profession, is one of the highest honours which can be attained by an individual engaged in aviation. My role, here, of course, is hardly that of an individual. In the narrowest justifiable sense, I can but speak for what has been accomplished by the 7,000 men and women who are the Pan American Airways System. That company, in itself, is singularly the product of a community effort of a large part of American industry. My purpose to-night, however, is to speak from an even broader viewpoint than that of a representative of any organisation or group of organisations.

It has been scarcely two years since civil aviation established the first scheduled air transport service across the North Atlantic—a goal toward which the airlines of many nations had been working for almost two decades. Were it not for the war, three nations, and perhaps six, would now be participating actively in the development of ocean flying along this major world trade route. Perhaps five nations would also have established operations on the South Atlantic. Yet the war has left only the United States in a position to carry on with scheduled trans-oceanic air transportation. Upon us, therefore, has rested the task of maintaining essential overseas air communications, as well as the responsibility for continuing the development of this vitally important phase of the air transport art. I have conceived my talk as a report upon the manner in which we have attempted to discharge that responsibility, together with a brief analysis of some of the technical development of the Pan American Airways System.

International air transportation throughout Europe began to develop swiftly before the end of 1919. It was not until October, 1927, that the first American international air service was inaugurated, when Pan American Airways undertook to establish scheduled operations between Key West and Havana. This, our pioneer effort, involved a 90-mile route across the Straits of Florida. From the very outset, the policy adopted by Pan American Airways required the use of multi-unit power plants. This we considered an essential requisite for over-water flying. Only aircraft so equipped could possibly provide the necessary reserve power which, even with the loss of one engine, should assure sustained flight through to destination, or safe return to the port of departure. In 1927, no marine-type aircraft had yet been developed in America suitable for air transport operation. The Fokker F-7 tri-motored landplane, with its demonstrated ability to maintain flight on two of its three engines, however, was soon to be available on the American market. Equipped with three Wright Whirlwind engines of 220 h.p. each, these planes could lift a gross weight of 9,700 lb., and had a cruising speed of 90 m.p.h. The wings, of wooden construction, lent themselves to the installation of flotation gear which contributed an additional safety factor. Even equipped with supplementary marine accessories, they permitted us to carry mail and eight passengers. These aircraft and the larger and improved Fokker F-10 tri-motored transports, available the next year, enabled us to extend service across the intervening over-water sectors of the West Indies as far south as Puerto Rico.

Between Puerto Rico and Trinidad, however, there were available no adequate sites for airports or intermediate fields which would permit the extension of this eastern route through the lower Antilles. Likewise, our projected western route, which branched from Cuba across the Straits of Yucatan, and thence through Central America to the Panama Canal Zone, required an entirely different type of aircraft. For these essential extensions of our service the Sikorsky S-38 amphibian was utilised. This pioneer American marine transport, capable of operating to and from both land airports and water areas, was equipped with two 420-h.p. Pratt and Whitney Wasp engines. Because of its inherent seaworthiness, it enabled us to carry seven passengers and mail within its gross weight limit of 10,480 lb., and to establish two trunkline routes, by following the perimeter of the Caribbean, between North and South America.

More powerful engines, and further departures in

* 29th Wilbur Wright Memorial Lecture, delivered before the Royal Aeronautical Society, in London, on June 17, 1941. Abridged.

hull and wing design, were incorporated in the first twin-engined American flying boats designed for transport use, the Consolidated Commodore, which made possible a next step, the first direct service across the 631-mile open-water sector between the Island of Jamaica and the Panama Canal Zone. In 1931, this represented the most ambitious over-seas operation so far undertaken by scheduled air transport. The Commodores permitted us to establish service, with restricted traffic loads, along this natural traffic artery between the continents. However, to carry commercially practical loads with adequate safety over such a long range required a four-engined marine aircraft much larger than any so far projected in the United States. A step toward this goal was the Sikorsky S-40, of which the first of three entered service early in 1932.

The development of these planes, built to specifications based on our growing experience, made an important contribution toward overseas transport. The impressive size of this ship, which could carry 40 passengers on the Miami-Havana run, and which has a gross weight of 34,600 lb., did much to break down the prevailing public resistance to over-water flying. They served as a convincing demonstration to designers and manufacturers of the potentialities of increased size and horse-power in aircraft for international—and, particularly, for over-water—operation. The S-40 type provided us with many new lessons in maintenance and surface handling of large-scale aircraft. Static conditions, typical of the tropical sphere of our operations, had required the use of radio telegraphy rather than voice communication. As a result, the standard Pan American Airways crew had always consisted of at least two pilots and a radio operator. Now, the use of four-engined aircraft led us to add a fourth member, an engine specialist. To insure accurate navigation across our trans-Caribbean sector, we undertook to adapt celestial navigation to air-transport purposes and to increase the range of our radio direction-finders. We also extensively supplemented our weather-service organisation to provide improved weather analyses for this overseas flying. Thus the Caribbean became a working laboratory in which we gained invaluable experience, to form the basis for future trans-oceanic operations.

For the first seven years of its history, Pan American Airways was engaged in the major and absorbing task of establishing an airline network between the Americas. First, by plane and muleback, by steamer and dugout canoe, went young engineers to blaze the trail, to carve airports out of jungle, to clear sites for weather stations in lonely mountain passes. Their assistants were Indians who had no idea of what an automobile might be and who had never heard of a railroad train. Following them went builders to construct hangars and passenger stations, hotels, and the two-hundred-odd weather observatories and radio control stations which to-day guide the aircraft between the Americas. By 1934, the initial stage was completed, with the extension of service to every important country and colony in the three Americas. Even while these airways were extending southward, development work had been well started toward a trans-Atlantic air line. Research expeditions, some entirely our own, others in which we were associated with American and European universities and scientific bodies, were dispatched to Iceland, Greenland, Labrador, and Newfoundland. Company engineers conducted similar surveys at the Azores, as well as in other points in Europe and Africa. Supplementary flight surveys were made in the Far North. Special weather stations were put aboard trans-Atlantic liners to aid in the development of a comprehensive weather-forecasting and reporting service.

Through these same years, our technical staff had been constantly studying the steady progress of aircraft and power-plant design in all its elements. As early as 1932, as a result of such studies, we felt justified in issuing tenders to manufacturers for the design and development of four-engine flight equipment which we hoped would permit the establishment of a seasonal trans-Atlantic service. Development of these aircraft contributed not only to our own progress, but also to the air transport industry as a whole. The Sikorsky S-42, of which the first was delivered to us in 1934, effectively disproved the prevailing theory that large heavier-than-air craft were not commercially sound; that the larger the plane, the less load it could carry in proportion to its weight. This plane, equipped with four 700-h.p. Pratt and Whitney "Hornets", cruised at 160 m.p.h. With a gross load rating of 38,000 lb. (increased in later models to 42,000 lb.), this plane had a ratio of useful to gross load of 36 per cent., a remarkable achievement for that time. These aircraft, of which we were to secure a total of ten, have done yeoman service in many regions. Equipped as a 32-passenger transport for ranges up to 1,000 miles, this fleet, until recently, was the nucleus of our express service to South America and along the east coast of that continent to Rio de Janeiro and Buenos Aires. Equipped with extra tanks, it permitted us to conduct survey flights on projected routes on the Pacific and the Atlantic.

The second type of ocean aircraft, the Martin M-130, equipped with four Pratt and Whitney Twin Wasps of 900 h.p. each, had a gross load rating of 52,000 lb. and an empty weight of only 29,500 lb. Two of these planes were delivered in 1935 and a third in the spring of 1936. Capable of carrying, with ample fuel reserve, a substantial load of mail and ten passengers on a non-stop flight in excess of 2,000 miles, this Martin Clipper thus gave us the physical means, as early as 1935, of establishing a trans-Atlantic service. We were not able at that time, however, to inaugurate actual flight operations on the North Atlantic.

In 1934, had begun an adventure in ocean air transport in an entirely different direction. To the west of us, across a chain of islands which were either territories, possessions, or associated commonwealths of the United States, lay an 8,683-mile route to the coast of Asia. Unable to move forward on the Atlantic, we applied our aircraft, our trained personnel, and the operating technique which we had developed in the Caribbean for the Atlantic service to the establishment of this trans-Pacific airway. In all respects, save those pertaining to difficult operating conditions of winds and weather, the physical task of building a trans-Pacific airway presented greater problems than did the corresponding project on the Atlantic. My use of the term "adventure" for this Pacific undertaking was an advised one. Honolulu, Midway, Wake, Guam, Manila—even the names of the ports of call of this projected air line lent story-book glamour to the enterprise. All the proposed bases offered harbours or lagoons satisfactory for seaplane operations. Docking requirements, the radio communication set-up, maintenance facility needs and fuel storage requirements, were problems which could be met, premised on past experience on other Pan-American routes.

Everything else varied grotesquely. Honolulu and Manila offered all the facilities, resources and advantages available in any well-developed centre of population. At these points our principal task was to install our radio and specialised base facilities. At Guam, radio and the base facilities would have to be supplemented by the construction of some sort of hotel facilities for passengers. On Midway Island, there was a small colony in charge of the cable relay station, but there were no facilities for newcomers. Wake was a tiny low-lying Vee-shaped atoll, a thousand miles from the nearest land. Exposed on all sides to the surf, it had no harbour protection of any kind. There was no vegetation save matted underbrush, no fresh water, no food, no shelter. We determined to tackle the task of setting up complete bases on all five of these islands, in a single expedition. On March 27, 1935, our colonising steamer nosed off through the Golden Gate on that four-months assignment. Never had a ship such a cargo or complement of passengers. Aboard her had been shipped two complete villages, five air bases, a quarter of a million gallons of fuel, 44 air-line technicians, a construction force of 74, food to feed them for months and, literally, 1,018,897 other items of equipment and material.

Even before this steamer reached Midway, early in April, on its arduous but successful mission, the Pan American Clipper, a specially fitted Sikorsky S-42, took off on a round-trip survey flight of the 2,402-mile sector of this route lying between San Francisco and Hawaii. Within the next few months, as each succeeding island base was set up and put into operation, this same Clipper conducted, step by step, flight surveys of the remaining legs of the route. The 1,304 miles between Honolulu and Midway, 1,185 miles between Midway and Wake, 1,508 miles between Wake and Guam, 1,589 miles between Guam and Manila, all were completed "without incident." With the delivery of the first Martin Clippers and the completion of its service test we were able to inaugurate on this route the first scheduled trans-oceanic air service for passengers.

In the meantime, our development work continued on the trans-Atlantic routes. Inquiries were released to manufacturers inviting tenders for more modern and efficient aircraft of higher cruising speed and greater payload. Early in 1936, we contracted with the Boeing Aircraft Company, of Seattle, for six four-engined flying boats to be known as the Boeing type B-314, which were to have a gross load rating of 84,000 lb., and to be capable of carrying 30 passengers in berths under average conditions across a 2,000-mile non-stop flight sector. New features to be incorporated in these ships were companion ways to permit accessibility to engines in flight and a flight deck ample for an entire crew, located above and completely separated from the passenger compartment. With such planes as these, we knew that we could substantially improve our service in the Pacific and be even more adequately prepared to set up a pioneer service in the Atlantic, which we hoped to be able to inaugurate several years later.

Unfortunately, as you so well know, international air transportation in its brief history has been confronted not alone with grave technical problems but also complicated political problems. With the adoption of the Paris Convention of 1919, covering international commercial aviation, followed by the Havana Convention and other similar enactments, the law of the air departed sharply from maritime traditions. There is no "freedom of the air." Every country now claims full sovereignty over its air space and no aircraft, even of a friendly Power in time of peace, can fly to or over the territory or territorial waters of any other country without direct permission or treaty authorisation. Such was the situation on both sides of the Atlantic. Before transport operations could be set up between the United States and Europe, many of these political questions had to be settled. It was not until 1937 that sufficient progress in the solution of these political problems had been achieved to permit the start of the actual trans-Atlantic survey flights.

From prior studies we knew that, so long as we were limited to aircraft which could not operate commercially on non-stop flights between the United States and European capitals, there were two general routes which offered best possibilities for a successful initial trans-Atlantic service. The first of these, for the purpose of convenience, can be referred to as the Great Circle Route to Great Britain and France via Canada, Newfoundland, and Ireland. The second, the Mid-Atlantic, extended from New York via the Azores and Lisbon. Bermuda offered possibilities as an alternate "stepping stone" on this Mid-Atlantic route. Winter conditions on the American, Canadian and Newfoundland coasts limited flying-boat operations on the Great Circle Route to a seasonal basis.

Between June and September, 1937, a series of five engineering surveys were conducted by Pan American Airways, utilising an S-42, especially equipped for flight research. Beginning on June 25, a preliminary survey covered the projected route from New York 601 miles to Shediac, New Brunswick, where an intermediate station had been established. A second continued from New York, via Shediac to Botwood, Newfoundland, 471 miles farther. In July, on the same day that a survey plane of Imperial Airways left Foynes, the Pan American Clipper took off from Botwood on the first transport survey of the critical 1,995-mile sector of this Great Circle Route lying between Newfoundland and Ireland. I need hardly put into words the regret of all of us in Pan American Airways that the course of history has not permitted our friends in the British air-transport industry to continue thus to fly at our side in scheduled, as well as survey, operations. The final survey over the Mid-Atlantic route was launched on August 16 from New York to Bermuda, and thence via the Azores and Lisbon to Marseilles. From Marseilles the Clipper continued to Southampton before return to the United States, again via Marseilles and Lisbon.

These surveys, conducted under strict transport routine, familiarised flight crews with the conditions at bases along the routes and served to confirm the adequacy of our technique as applied to trans-Atlantic operations. In spite of the comparatively mild season of the year, these flights also confirmed our respect for the difficult weather problems of the Atlantic area. Winds at altitudes at which we planned to operate proved even stronger and more stubborn from the west than we had expected. Final ocean swell observations in the Azores forecast a difficult operations problem at that essential refuelling point.

These surveys were completed in 1937, but conditions arose during the following year to postpone further the institution of a scheduled service, and it was not until May 20, 1939, that the Yankee Clipper, first of our new Boeing B-314 ocean transports, headed out from New York for Europe on official flight No. 1, instituting the first scheduled aeroplane mail service over the Atlantic ocean. By June 24, scheduled service had been inaugurated across both the Great Circle and Mid-Atlantic routes. By July, passengers as well as mail were being carried in both directions on regular weekly schedules to Southampton and to Marseilles.

This pioneer service, confronted by many problems of its own, was soon to be affected by circumstances of a more serious nature. Three months after the service started, it became obvious that war was imminent in Europe. It would be necessary to withdraw the terminal of the Great Circle Route from Southampton to Foynes, in neutral Ireland, and similarly to withdraw from Marseilles to Lisbon on the Mid-Atlantic Route. Early in October, as had been foreseen, weather conditions along the Great Circle Route required us to consolidate both services along the New York-Lisbon airway with a single intermediate stop at the Azores. If it had not been for the war, of course, we would have continued directly to serve Southampton via Lisbon. In the spring, we would have re-established service across the Great Circle Route if the Neutrality Act had not intervened

to make the area to the west of Ireland a combat zone. All flight operations have since been conducted across the Mid-Atlantic and southerly routes. From an operating problem point of view, the Atlantic during the past two years, has lived up to its advance reputation. Even during the first months of operation, prior to the outbreak of war, difficulties already encountered were sufficient to confirm the North Atlantic as being, technically, the most difficult operation of any major aerial trade route. The outbreak of war, forcing curtailment of regular steamship services, left the trans-Atlantic air route one of the most important arteries between our two countries. Traffic demand, which had been encouraging but not spectacular in the early months of service, climbed swiftly to volumes ten times greater than the original estimates.

A few months after the opening of operations in 1939, and shortly after the outbreak of war, we released an order for six additional Boeing B-314A transports for delivery early in 1941. Four of these have now been delivered, three of which have been transferred to the British Government. The remaining aircraft on this order should enable us soon to increase our frequency of service from three to six round tips each week on the Atlantic. Meanwhile, we have taken every step which might increase payload capacities. We have been able to make changes in engines and propellers, to increase operating efficiency, and decrease fuel loads. Every spare ounce of furnishings, equipment and even paint has been stripped from the Clippers for the same purpose. Instead of operating all schedules non-stop between Bermuda and Lisbon, as the improved B-314's are now capable of doing, we schedule flights into and out of Horta, whenever weather and sea conditions permit, in order to make available the approximately 5,000 lb. eastbound and 3,000 lb. westbound additional payload.

The flight logs show how difficult were operations through the winter of 1939-1940. Many flights were delayed due to harbour conditions at Horta. Others were cancelled due to extremely strong westerly winds and mid-ocean storms covering areas too wide to detour; and still others, when flown, were able to carry only very limited westbound payloads. As a result, we surveyed and put into operation during this last winter of 1940-1941 a route for westward crossings which swung far south from the usual route. Heading south from Lisbon, the Clippers landed at Bolama in Portuguese Guinea, West Africa, then turned westward to Belem in Brazil, thence northward to New York via Trinidad, and either Puerto Rico or Bermuda. Such a route, while 4,085 miles longer than the Lisbon-Azores-Bermuda-New York route, and correspondingly more expensive to operate, nevertheless substantially offset the increased cost in the improvements effected in the percentage of schedules completed and the number of passengers, in addition to mails, moved from Europe to the United States.

By overflying Horta on eastbound trips throughout the winter and following the South Atlantic route on westbound trips, the Clippers were able to complete 50 per cent. more westbound crossings than during the previous winter. Of a total of 25 trips scheduled, only 14 were completed in three winter months of 1940. In 1941, 21 of these flights were completed via the southern route, a record of 84 per cent. performance against 56 per cent. for 1940. Traffic-wise, the change of route proved equally satisfactory. In the winter of 1940, only 286 persons were carried from Lisbon to New York. During the winter of 1941, this total reached 471 for the period, and this in spite of an increase of mail loads from 33,247 lb. to 45,404 lb.

(To be continued.)

REGISTRATION OF BUILDERS.—The registration of all builders throughout Great Britain has been decided upon. This constitutes a further step towards the increased output which was referred to by Lord Reith, Minister of Works and Buildings, when explaining recently the reasons for the application of the Essential Work Order to the building industry. Details of the registration will be issued shortly. Every builder will be obliged to state the number of men, skilled and unskilled, he is employing and the work he is engaged on. Information will also be issued, in due course, regarding the establishment of the National Building Council. This will consist of representatives of all sides of the industry under independent chairmanship. The chairman has not yet been selected, but the greatest possible care is being taken to find a man whose eminence and authority are such as to inspire the confidence necessary for this difficult office. The function of the Council will be to facilitate the smooth working of the industry and to ensure a state of mutual trust, so that all concerned will be able to direct their full effort to the vital work before the industry. Further steps towards the elimination of non-essential building work will also be taken shortly.

LABOUR NOTES.

A DEPUTATION composed of Labour Members of Parliament for coal-mining constituencies and members of the executive committee of the Mineworkers' Federation of Great Britain discussed last week with the Minister of Labour and National Service and the Secretary for Mines the question of man power in the coalfields with the object of increasing output. Several of the points set down in advance, for consideration, as was indicated in these notes a week ago, had already been dealt with. For example, the suggestion that miners should be recalled from the Armed Forces had been answered; men in the Forces are not to be released. Mr. Bevin told the deputation, however, that he had issued a "standstill" order on the calling-up of more miners. He hoped, he added, to be able to bring back to the industry a large number of former miners. An official account of the discussion said:—"The representatives of the Federation undertook to co-operate, and they agreed to appoint a small committee to advise the Minister. A number of difficulties were discussed, including regrading of workers in order to use the total labour pool more economically; improvement of transport services, and means of attracting back to the mines as many ex-miners as possible. The Minister assured the Federation that in so far as this was done, he would do all in his power to safeguard the men against unemployment in the event of slackening in the industry during the winter."

Replying to a question in the House of Commons, the Minister of Labour and National Service stated that on the basis of such information as was available relating mainly to rates of wages fixed by collective agreements, arbitration awards or statutory orders, it was estimated that the average rise in the level of weekly full-time rates of wages between September 1, 1939, and June 1, 1941, was about 20 per cent. The official cost-of-living index figure rose by 29 per cent. between September 1, 1939, and May 31, 1941.

In a letter published in a recent issue of the *Manchester Guardian*, Mr. G. W. Taylor suggested that there was one sure way of increasing the production of establishments engaged on war work. This was, he said, "the placing of orders on a much larger scale than hitherto by the Service Departments." If the orders were there, he went on to say, industry would respond, and if the work was there waiting for the men on the machines, they would work harder to rid themselves of the accumulation and improve their earnings. Furthermore, he added, employers would be encouraged to utilise female labour, of which there was an abundance, for women were eminently suitable for dealing with production jobs freed from too many complicated settings.

In Mr. Taylor's opinion, the volume of work which is being placed by Government departments is insufficient to keep many sections of engineering fully employed, and orders are sometimes placed, withheld or delayed in relation to statistics of previous months' output, without taking into account factors that make those statistics not only useless but misleading. "If," he writes, "the Government will ensure an adequate supply of raw materials, and, at the same time, think and act in terms of much greater production, then industry will do the rest and do it quickly."

Another interesting contribution to the discussion of this aspect of the production problem was made by Mr. Cuming Butler, chairman of Messrs. Butlers, Limited, Birmingham, in a letter to *The Times* on Saturday last. He said in the course of it:—"Very few factories can organise their production so as to keep all their machines working all the time. In the making of a complete article some processes are more quickly carried out than others and the machines used for these purposes are finished first and then have to lie idle until the next lot of work is being made. If all factories so circumstanced were asked to make an inventory of machines not always working and gave the approximate number of hours per week, or per month, that they are standing idle, arrangements could be made for them to be used for other firms' work and so increase production over the country as a whole."

In August last the National Arbitration Tribunal gave an award affecting the newspaper and printing industry, increasing the wages of men and women on men's work by 5*s.* a week, those of other women by 2*s.* 6*d.* a week, and those of male and female juveniles by 1*s.* 6*d.* a week. An appeal for an interpretation of the scope of the award by *The Yorkshire Post* and the National Society of Operative Printers and Assistants was heard recently by the Tribunal which decided, it is understood, that the increases were on basic rates. "Consequently," *The Newspaper World* says, "a firm voluntarily paying in excess of the basic rate is not legally liable automatically to advance wages by the amount of the August award."

Details of a mutual assistance scheme for industrial undertakings in Germany are given in the May issue of the *International Labour Review*, a publication of the International Labour Office whose headquarters are now in Montreal. An Order, it is stated, was issued in Germany on February 19, 1940, laying down the principle of compulsory mutual assistance for the maintenance of undertakings which had to close down on account of the war. The details of the scheme of mutual assistance were given in a Second Order issued on May 3, 1940. According to the preamble to the first Order, the object of the measure was to provide financial assistance, whenever such assistance was justified, for the purpose of protecting the existence of undertakings of economic or social utility which, owing to the war, had had to interrupt their activities, and of enabling them to resume operations in the future. The necessary funds were to be provided by the undertakings whose activities were increased in consequence of the war. The application of the Order was entrusted by the Ministerial Council of National Defence to the industrial groups in the National Economic Organisation. According to the Second Order, the industrial groups may now issue such instructions as they consider necessary.

The assistance scheme is primarily intended for industry, but may be extended also to commercial undertakings, insurance companies, etc. Shipping is excluded. The sums to be paid to undertakings covered by the arrangement are to include the following items of expenditure: (1) repairs; (2) heating and lighting; (3) pensions and salaries; (4) the pay and other expenses of supervisory staff; (5) the rent of premises; (6) the rent of machinery and other movable equipment; (7) interest on debt; (8) insurance premiums; (9) the cost of licences and patents; and (10) contributions to occupational organisations. Certain conditions must be complied with before assistance is given. Thus, the interruption of the activities of the undertaking must be a direct outcome of the war and must, as a rule, be complete. The undertakings must be unable to resume work at the end of the war if dependent on its own resources alone. Lastly, the undertaking must be deemed to be useful to the national economy after the war and deserving of assistance.

The new Act relating to the labour courts set up in Venezuela also provides for the creation of labour legal advice offices whose officials or special attorneys may be called upon to assist and represent workers before the labour courts or before any official body in differences arising out of labour or social welfare questions. Their services are expected to be specially valuable in the case of claims on behalf of minors or of other persons who are under some legal incapacity and have not procured legal representatives, or, in the case of industrial accidents, when the injured person is himself unable to lodge a claim. The labour inspectors must call the attention of the labour legal advice offices to cases in which their intervention is required.

Labour legal advisers will answer free of charge any request for information concerning the interpretation of labour laws, rules or regulations or any question concerning establishment rules, individual contracts of employment, collective agreements, and any other matter affecting the interests of workers. The legal advice offices must be open during four hours on every working day, and at least two of the four hours must not conflict with the ordinary working time of the majority of the workers in the locality. The object of that provision is stated to be to make it possible for workpeople to obtain free legal advice without having to leave their work and thereby incur a loss of wages.

It is stated that in virtue of agreements concluded at the beginning of February, the number of Italian workmen transferred to Germany for employment in German industry has been substantially increased. In order that Italian production may not be slowed down by these transfers, measures have been taken to compensate the reduction in the labour force by an extension of hours of work. In metal working and kindred establishments where work is being carried out continuously throughout the 24 hours, the three-shift system is to be replaced by the two-shift system, each shift working 12 hours a day and 72 hours a week. In establishments where the working day is less than 24 hours, the normal hours of work of each employee are to be 10 in the day and 60 in the week.

THE ANNEALING OF HIGH-NICKEL ALLOYS.

MATERIALS after being cold worked by rolling, drawing and other forming operations, are usually subjected to an annealing process to relieve the stresses imposed, and the nature and degree of the annealing treatment naturally varies with the class of material employed. Nickel and high-nickel alloys work-harden more rapidly than mild steel and consequently require to be annealed more frequently; furthermore, greater care is necessary than is customary with steel. For the guidance of users, some useful directions for the annealing of Monel, nickel and Inconel are given in a well-written pamphlet recently issued by Messrs. Henry Wiggin and Company, Limited, Grosvenor House, Park-lane, London, W.1. In this publication, emphasis is laid on the necessity for adhering fairly strictly to a prescribed time-temperature cycle. Obviously, under-annealing gives a product which will fall short of the requisite degree of softness, while over-annealing will produce a coarse crystal structure which is detrimental from the point of view of physical properties and will often impair the surface finish. The range of temperatures employed in the heat treatment of materials containing high percentages of nickel varies from 300 deg. C. for relieving stress in certain nickel-copper alloys to as high as 1,000 deg. to 1,050 deg. C. for the full softening of the 80 : 14 : 6 nickel-chromium-iron heat and corrosion resisting alloy Inconel. The annealing temperatures and times quoted in Table I are intended as a guide in average practice.

TABLE I.

Material.	Temperature.		Time.	
	Deg. C.	Deg. F.	For Subsequent Mechanical Operation.	For Subsequent Hand Spinning.
			Minutes.	Minutes.
Monel and "K" Monel*	930	1,700	2–5	5–10
	980	1,800	½–2	3–5
Nickel .. .	900	1,650	2–5	5–10
	950	1,740	½–2	3–5
Inconel ..	980	1,800	5–10	10–15
	1,040	1,900	1–3	5–10

* "K" Monel is produced by the addition of up to 4 per cent. aluminium to Monel.

After heating the work may be allowed to cool in air, or the pieces may be quenched in water containing 2 per cent. of alcohol to reduce the oxide "flash" formed in drawing them out of the furnace. The work should be transferred from the furnace to the quenching bath as quickly as possible and it should be allowed to remain for a few minutes in the bath before being further cold worked. Methyl alcohol should be used for the quenching solution; de-natured grain alcohol is stated to be not so effective.

Practically all primary products, such as strip, sheet, rod and wire, are now almost invariably bright-annealed at all stages in their manufacture and this eliminates the need for pickling. Such material should, therefore, not be impaired in the course of further processing by annealing in an open furnace, and, for this reason, manufactured articles such as stampings and pressings are being increasingly bright-annealed. On the other hand, batch-type furnaces are widely favoured for such parts as rivets, wire in coils and similar work, which are annealed in boxes. The fuel and furnace restrictions are not so stringent as in open annealing, as the furnace atmosphere is excluded.

TABLE II.

Material.	Temperature.		Hours at Temperature.
	Deg. C.	Deg. F.	
Monel and "K" Monel ..	760	1,400	2–6
Nickel	760	1,400	2–6
Inconel	820	1,500	2–6

Almost any type of furnace can be employed, but fuels containing high sulphur should be avoided. After the box has been charged into the furnace it should be brought rapidly up to the temperature. The total time in the furnace depends on the size and weight of the box and the charge, and on the furnace heating capacity. The recommended temperatures and times (taking into account the time necessary for the heat to penetrate through the entire charge) are given in Table II. If the temperature be allowed to go beyond the limits given, the heating time should be reduced. At 900 deg. C. (1,650 deg. F.), Monel and nickel will anneal in from 1½ hours to 2 hours, and should not be heated longer in this temperature region on account of the danger of over-annealing and the development of coarse grain.

Substantially improved elastic properties may be developed in Monel, nickel and Inconel by a stress-relief annealing operation after cold-working. This operation has the advantages of minimising the tendency of cold-drawn rods to distort when the skin is broken by machining and of causing a substantial improvement in the limit of proportionality of the material as compared with that of metal in the rolled or drawn condition. Moreover, the stress-relief annealing of perforated sheets, after the perforating operation, minimises the tendency to stress cracking to which the material in the as-rolled condition may be liable on exposure to corrosive agents containing mercuric salts or ammonia. For Monel and nickel the stress-relief annealing temperature is 300 deg. C. (570 deg. F.), and for Inconel it is 400 deg. C. The annealing time is two hours in each case. Open annealing may be used, as the temperature is too low to cause appreciable oxidation.

THE AUTOMATIC ADJUSTABLE-BLADE TURBINE.*

By R. V. TERRY.

THE idea of adjusting the pitch of the blades of hydraulic-turbine runners to suit the load is relatively old. Such a runner was described in 1867. For about 25 years, development has been in progress on the Kaplan adjustable-blade propeller type turbine. That type has reached a high degree of perfection in employing an oil-pressure system, associated with the governor-pressure system, to operate the runner blades in synchronism with the gates. The principal advantages are: (*a*) increase in capacity above normal; (*b*) sustained efficiency over the larger part of the load range; (*c*) reduction of the minimum head at which the turbine will develop power; and (*d*) greater stability of operation, particularly at low and intermediate loads. In 1928, the author began studies for an adjustable-blade type of runner wherein the blades would move automatically with changes in flow through the runner, as well as with changes of speed and head. It was his rather radical idea so to pivot the blades with reference to their centres of pressure that they would tend to adjust themselves to the most efficient angle for each condition of gate opening and head for constant-speed operation.

Surprisingly satisfactory results were secured with the first models built and tested in 1930, which encouraged further experimentation. Other groups of tests have been conducted at intervals for the last 10 years. Altogether, more than 200 tests have been made on about 30 different models, using about 15 sets of blades, some of which were altered as the test programme progressed. The model tests were made on 16½-in. diameter runners under heads varying from 9 ft. to 12 ft. in the Newport News hydraulic laboratory.

It was early found that the blades must be pivoted considerably ahead of their centres of area; in fact, this was predicted from a study of the characteristics of airfoils and hydrofoils. In order that the blades might have a tendency to adjust themselves automatically and with minimum operative moments, it was also found desirable to pivot them slightly ahead of their centres of pressure. This resulted in a tendency for the blades to open at all times, at least in normal operation, at or near the best efficiency conditions. As the test programme progressed, certain definite trends and characteristics were found which influenced subsequent designs.

It is assumed that those interested are somewhat familiar with turbine design and with some of the terms used in aeronautics, dealing with airfoils. In Fig. 1 (upper left), page 18, are given typical velocity diagrams for an average blade section. Diagram u_1, c_1, w_1 is for the inlet edge of the blade, while diagram u_2, c_2, w_2 is for the discharge edge. Terms w_1 and w_2 represent the respective velocities relative to the blade and w_a is the vectorial average of w_1 and w_2. The function $u_1 = u_2$ is the tangential velocity of the blade. Terms c_1 and c_2 are the absolute velocities at inlet and discharge, respectively.

A typical blade section is also shown in Fig. 1, with chord C and mean camber c. The angle of attack α is the angle the inflowing water w_1 makes with the chord C. The centre of pressure is shown at point y, which is at distance n from the leading edge of the blade, measured along the chord. The pivotal axis is shown by point x, which is at distance m from the leading edge of the blade. The equivalent total force on all the blades is represented by F, while T represents the axial component of F, or the hydraulic thrust. The "hydraulic moment," tending to open the blades, is Fa, a being $n - m$. The hydraulic moment is balanced by a "reactive moment" Rb, tending to close the blades, produced by a balance piston in the runner hub acting on the blades with lever arm b, R being the total piston load.

An analysis of tests on airfoils similar in shape to turbine blades shows that the distance of the centre of pressure (point y in Fig. 1) from the leading edge in proportion to chord length or $\frac{n}{C}$ reaches a minimum value at a moderate angle of attack α, approximately the most efficient angle of attack in the case of a turbine blade. The curve of $\frac{n}{C}$ plotted against angle of attack is fairly flat for several degrees variation in α from the value giving minimum $\frac{n}{C}$; but on either side of that value the centre of pressure travels downstream, as shown in Fig. 2, on page 18. A further analysis of the characteristics of airfoils shows that the location of the centre of pressure varies with the proportional mean camber $\frac{c}{C}$. This variation (Fig. 3, page 18) has been found to be fairly accurately expressed by the formula

$$\frac{n}{C} = 0{\cdot}25 + 2{\cdot}25 \times \frac{c}{C}.$$

Thus, a blade section with a mean camber of 8 per cent. would have its centre of pressure located at 35 per cent. chord, and should be pivoted at about 33 per cent. chord. The proper camber of turbine blades gradually decreases from the hub to the periphery, with a resulting change in the location of the centre of pressure. We are primarily interested in the location of the centre of pressure of the blade as a whole, rather than in its location for each individual section. It has been found more practicable, in producing simple blade shapes, to place the axis farther downstream near the hub and farther upstream near the periphery, producing an over-all result as though detail considerations were given to pivoting each section upstream from its individual centre of pressure. The runner blade is usually divided into four annular sections of approximately equal discharge and consideration given to the average result, while Fig. 4, on page 18, shows a sectional view of the model runner with six blades, and Figs. 5, 6 and 7, on the same page, shows, a typical layout of a runner blade.

As may be expected, it was found that blades in echelon, grouped around a common hub and enclosed in a housing, do not act exactly as they do in the case of single airfoils tested in infinite space. The echelon arrangement, together with the reactive nature of a turbine runner, tends to move the centre of pressure somewhat downstream. This tendency has been found to increase with the camber, number of blades, and with blade width or overlap. An idea of the degree of movement of centre of pressure may be had from Table I, herewith.

TABLE I.—*Comparison of Adjustable-Blade Runners from Tests on Models 16½ in. in diameter.*

Relative Blade Camber.	Normal.			Small.
Number of blades ..	4	5	6	6
Type No.	164	165B	166B	179D
Best unit speed, N_1 ..	200	180	160	160
Specific speed, N_s ..	160	140	120	120
Pivot point, per cent. of chord :—				
At hub	34	37	40	36
At periphery	24	27	30	21
Average	29	32	35	28·5
Mean camber, per cent. of chord :—				
At hub	7·7	8·7	8·4	7·1
At periphery	2·3	3·1	3·6	2·5
Centre of press., per cent. of chord :—				
At mean flow line ..	31·0	34	37·0	30·5
From airfoil tests ..	30·0	31	32·5	30·5
Discharge angle at periphery, deg.	14·5	16	18·5	18·5
Chord angle at periphery, deg.	17	19·5	22	21
Hub diameter, per cent. of outside diameter ..	40	42·5	45	45
Pitch at hub	0·88	1·06	1·09	1·09
Pitch at periphery ..	0·77	0·88	1·00	0·91
Blade area, per cent. of annular area	95	114	128	117
Head range (approx.), ft.	10–40	25–55	40–70	—

The test procedure for developing a model was as follows:—(1) Design the blades, based upon data secured from previous tests and from the consideration of the characteristics of airfoils.* (2) Test the model for speed, power, and efficiency at several blade

* Paper entitled "Development of the Automatic Adjustable-Blade Type Propeller Turbine," presented before the American Society of Mechanical Engineers, New York, December, 1940. Abridged.

* "Aerodynamic Characteristics of Airfoils—VI," National Advisory Committee for Aeronautics, *Technical Report* No. 315 (1929).

AUTOMATIC BLADE ADJUSTMENT FOR WATER TURBINES.

Fig.1.

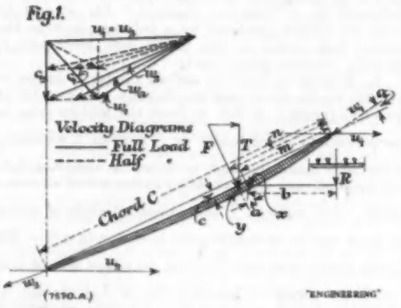


Fig.2.

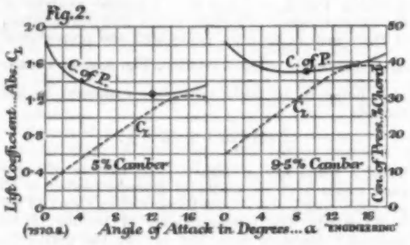
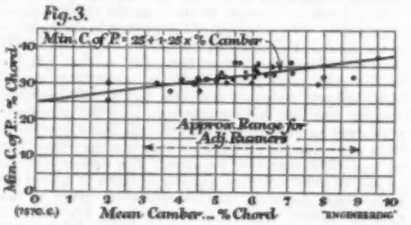


Fig.3.



positions, usually six, with the blades locked. (3) Unlock the blades so that they are free to assume a balanced position at different operating conditions. Calibrated springs with various amounts of compression are used to produce reactive moments tending to close the blades. (4) Plot moment diagrams, one for each of several speeds, as illustrated in Fig. 8, on this page. (5) Study the required reactive moments for best efficiency operation, best gate-blade relation, for each speed, and reduce them to a constant speed for variable-head operation. In analysing the moments, gravity effects are also considered. (6) Put the model in automatic operation with a suitable reactive moment with the wicket gates under governor control, driving an electric dynamometer, to determine its behaviour under starting and runaway-speed conditions, as well as under normal power-producing conditions. (7) Finally, determine the movement of the centre of pressure from the test data. This is done primarily from a consideration of the measured hydraulic moments and from the calculated thrust; however, some blades are tested with two locations of the axis, and the centre of pressure computed from the two sets of hydraulic-moment data.

From Figs. 5, 6 and 7, it may be seen that the general shape of blades is quite simple. A cylindrical section approximates that of a portion of a parabola, with which uniform deceleration of the absolute whirl component of the water is theoretically obtained. The maximum camber is placed at about one-third the chord distance from the leading edge of the blade. The face and back of the blades over most of their area are each produced by a system of straight lines (for horizontal sections) meeting at a common point, at the runner axis for the face and near the axis for the back. The blades are laid out for an intermediate angular position, usually for the 60-per cent. open position. The pitch is made uniform on each radial line; however, the inlet edge of the blade is extended at the hub, resulting in greater pitch at that point. Cambers much greater than those theoretically required from a consideration of velocity diagrams are selected, to allow for the bending effect of the water streams before and behind the runner.

As a result of tests to date the following general conclusions may be drawn:—(1) The blades tend to follow the gates, therefore tend to open as gates open and vice versa. (2) With proper blade shape and pivoting, a reasonably constant reactive moment may be used for operation at constant speed at or near best efficiency, for the various gate openings and for varying unit speeds as the head is changed. (3) At low unit

Fig.4.

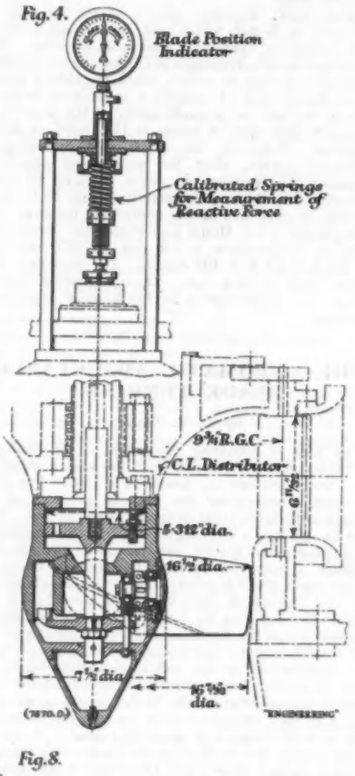
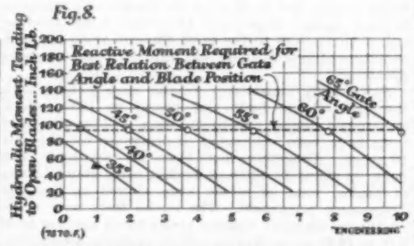


Fig.8.



speeds and high heads for constant speed, the required reactive moment for best efficiency decreases somewhat as the load increases; that is, with a constant reactive moment, the blades move less than is required for perfect synchronism with the gates. (4) At high unit speed and low heads, the blades tend to move more than is required for the best gate-blade relation. (5) When properly pivoted, the blades have a strong tendency to open when starting the wheel from rest. This tendency is greatest with 4-blade, and decreases with 5-blade and 6-blade runners. (6) The blades have a strong tendency to open if the runner runs away at a constant head. This effect is least with 4 blades and greatest with 6 blades. The hydraulic moment at runaway speed usually ranged from 4 to 5 times normal with the models tested. At the present stage of development, it is not considered practicable or even possible to explain all the various characteristics by mathematics and hydrodynamics. The problem is too complicated, considering the numerous variables. However, a discussion of a few concepts is perhaps in order.

Why should the reactive moment required for best efficiency be fairly constant for varying loads and heads? To start with, the turbine drives an electric generator at a constant speed. The tangential velocity is relatively high compared with the variable axial velocity. The result is a fairly constant relative velocity w_a, which is one that produces the predominant dynamic effect on the blades. For best efficiency under the various operating conditions, the angle of attack is naturally about the same, resulting in approximately the same centre of pressure location. A constant relative velocity, together with a fixed angle of attack and centre of pressure, would, of course, create a constant hydraulic moment.

Why should the moment increase as the gates are opened? As the gates open, the angle of attack increases. This causes a slight movement of the

Fig.5.

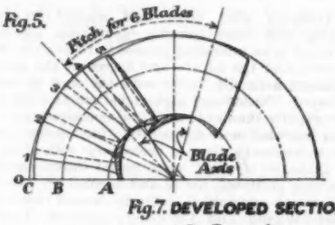
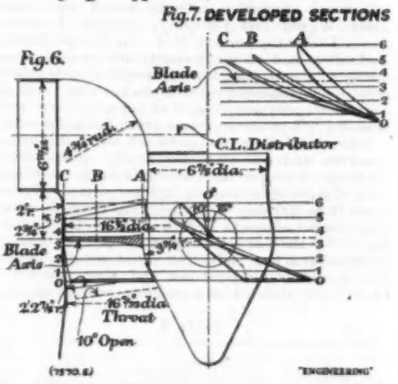


Fig.7. DEVELOPED SECTIONS

Fig.6.



centre of pressure downstream, and an increase in the normal force, resulting in increased moment. This change in conditions overbalances the reactive moment and the blades move open. However, as the blades move open, the angle of attack and normal force decrease and the centre of pressure moves upstream until a new balanced condition is reached.

Why do the blades open when starting the turbine? With the runner at rest the water from the gates impinges directly against the runner blades at a very large angle of attack. Under this condition the centre of pressure is located well downstream with reference to the axis of the blade. Because the blade is stationary and the angle of water deflection large, the force on the blade, per unit volume of water and head, is relatively high. This results in a large opening moment that overbalances the designed reactive moment at a relatively small gate opening. With 4-blade runners, the blade area is considerably less than the annular area between the hub and periphery. The blades of such runners have a very strong tendency to open when starting and the blades will go wide open. With 5-blade runners, and particularly those with 6 blades, the overlap of the blades may be such that the leading edge of one blade obstructs the impingement of water on the next blade. This results in less movement of the centre of pressure and a smaller opening moment. Consequently, the blades of such runners do not open as much when starting.

Why do the blades open when the wheel runs away? Under this condition two more or less opposing actions take place. One consists of a reduction in the angle of attack, which tends to reduce the blade force and moment. The other consists of an increase in the relative velocity, which tends to increase the force and moment approximately as the square of that velocity or speed. The latter action is predominant, resulting in rapidly increasing moment, particularly at the higher speeds. Here again there is a considerable change in characteristics as the number and overlap of the blades is increased. The opening tendency is stronger with the larger number of blades.

Tests were also made to determine the effect of the shape of the throat ring below the axis on the power and efficiency characteristics, as well as on the hydraulic moment on the blades. These included spherical, cylindrical, and intermediate shapes. As was expected, the spherical shape had an effect in moving the centre of pressure downstream as the blades approached their open position. It was found better to make the ring cylindrical for 4-blade runners and somewhat curved for the 5-blade and 6-blade runners. At the higher specific speeds, it was found that, for a given diameter of runner, the reduction in power caused by spherical ring more than offsets any gain in efficiency at the largest blade angles. When efficiency was plotted against power, the curve for a cylindrical ring was slightly above that for a spherical ring near full load. At low and intermediate loads, no difference was found.

The model tests have established a relation between the centre of pressure and the axis of the runner blade which should direct attention to the advantages in utilising the minimum force to move any type of adjustable blade runner. When the blades are pivoted

AUTOMATIC BLADE ADJUSTMENT FOR WATER TURBINES.

Fig. 9.

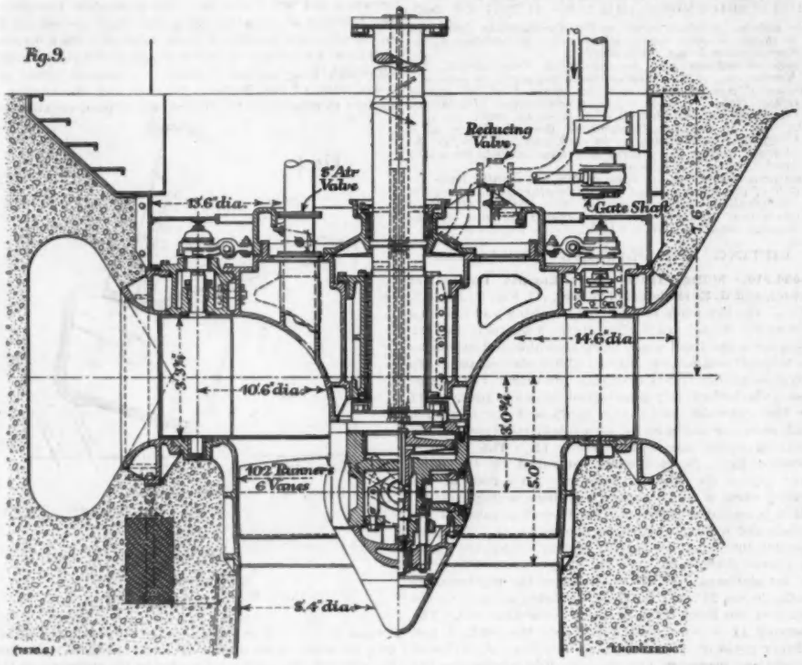


Fig. 11. SECTION A A

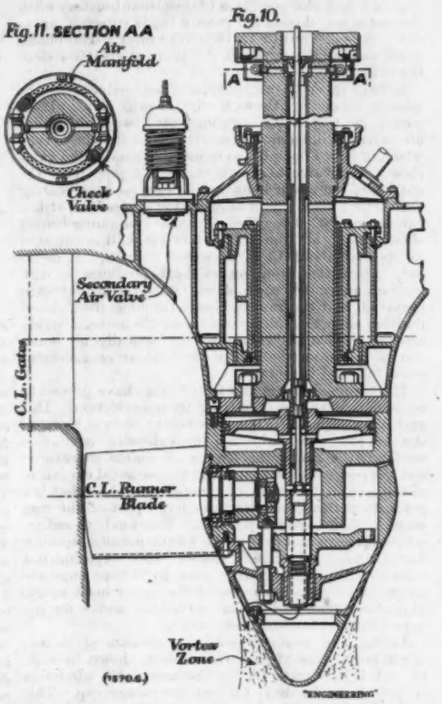


Fig. 10.

too far downstream, large moments are produced, particularly at runaway speeds. If the axis of the blade is moved upstream, closer to the centre of pressure, the force needed to move the blades is smaller and the machine is safer from the standpoint of overspeed. However, without the use of antifriction bearings, there is a possibility of encountering the combination of blade and gate opening for maximum runaway speed, and the generators have to be designed for such possibility.

With the new type of adjustable-blade turbine, and with the blades properly pivoted ahead of the centre of pressure on roller bearings, the theoretical maximum runaway speed cannot conceivably be encountered. The maximum runaway speed combination occurs at high gate opening with the blades nearly closed, and may be from 2·3 to 2·5 times the normal speed, or even higher. With the blades allowed to open fully, the runaway speed is held within 1·8 to 2 times normal, the overspeed for which standard generators are designed; also, the force required to move the blades is only a small fraction of that needed when the blades are not appropriately pivoted with respect to the centre of pressure.

By 1934, it was considered that sufficiently satisfactory results had been obtained in the laboratory to justify an experimental field installation. Arrangements were made at that time with the Kanawha Valley Power Company to furnish a 14-ft. 9-in. adjustable runner instead of a fixed-blade runner at the Marmet plant near Charleston, West Virginia. This unit was placed in operation in 1935, and has been in continuous use since that time. It is rated at 7,600 h.p. under 23-ft. head at 90 r.p.m. and has developed about 8,500 h.p. under that head. With the exception of the runner and a few minor differences, the adjustable blade unit is identical with the adjacent fixed-blade turbine, rated at 6,600 h.p. Two other turbines of essentially the same design have since been put into operation for the same company, one in 1937 at the Winfield plant, rated at 9,150 h.p. at 26-ft. head, and one in 1938 at the London Plant, both near Charleston, West Virginia.

The Marmet turbine represented a rather large step-up in physical dimensions and power from the model, especially for equipment of such radical departure from past practice. The areas of the water passage were about 115 times and the power about 300 times those of the model. With these three installations, the connection between the four blades of the runner and the balance piston was of the rack-and-gear sector type, each rack being guided in two bearings. The eight rack bearings cause some friction, which creates a lag in the blade position with reference to the wicket gates and results in some differences between increasing and decreasing loads, amounting to about 10 per cent. in gate opening or about 3 deg. in blade position. These differences are not considered important. Field efficiency tests of those installations were not made because of the difficulty of measuring the water accurately; however, the average blade position with respect to gate opening closely follows the best relation determined from the model tests. The power output plotted against gate opening approximates to a straight line, which is a desirable characteristic.

The fourth installation was made during the last year at the Austin Dam plant of the Lower Colorado River Authority and consists of two units, each rated at 10,000 h.p. at 200 r.p.m., and 61 ft. head. Preliminary field-test results show a maximum efficiency of 92 per cent. This installation may be considered typical and will be briefly described by reference to Fig. 9, on this page. The six runner blades are of cast steel, with integral trunnions pivoted on roller bearings in a cast-steel hub. Each blade is pivoted on three roller bearings, two radial bearings, and a thrust bearing. The runner hub is divided into two compartments. The lower compartment, which is packed with grease, carries the bearings and blade-connecting mechanism. The upper compartment consists of a bronze-lined cylinder to house the reactive piston, the integral stem of which projects downward through the lower compartment for connection to the blades by spider, links, and levers. The hub is also provided with top and bottom covers of cast steel, the top one being arranged for connection to the shaft. The stroke of the piston and spider limits the travel of the blades to 25 deg. The piston rod is guided in two bronze-bushed bearings, made equal in diameter so that the reciprocation of the piston will not create a pumping action on the grease in the lower hub compartment. The space under the balance piston communicates with the draft tube through ports in the piston hub, the hollow piston rod, and ports in the lower cap of the runner. Reactive pressure on top of the piston, tending to close the blades, is supplied from the headwater, through strainers and a pressure-reducing valve, to the bearing housing, thence through radial holes in the shaft and downward through the hollow shaft. This supply is combined with the water supply to the rubber bearing. The pressure supply is maintained constant by the pressure-reducing valve, the adjustment of which may be easily altered in the field as desired.

Grease is supplied to the runner hub through a pipe connected internally to the piston rod and extending upward through the generator and turbine shafts. This pipe also actuates the blade position indicator which is mounted above the generator. The top end of the pipe is provided with a swivel connection for greasing the runner hub while the turbine is running.

The runner hub is packed with grease during assembly. A heavy-bodied adhesive grease is used. It is expected that some water will enter the hub; this is made difficult, however, by the use of the heavy-bodied grease and by the use of a labyrinth-type seal at the blade bosses. The roller bearings are of the 15 to 18 per cent. chromium type of corrosion-resisting steel, with a Rockwell C hardness of about 55. In addition to creating the reactive moment, the piston in the upper part of the runner hub also serves as a very effective dashpot. The inflow to and outflow from both sides of the piston must pass through restricted openings. This dashpot action helps to steady the blade movement as well as to limit the rate of movement.

The mechanism in the runners of all installations is simple and rugged. The blades are pivoted only slightly upstream from their normal centres of pressure, approximately 1 per cent. of the nominal diameter of the runner. During normal operation this results in rather small moments about the blade axes, and relatively small forces on the internal mechanism, tending to reduce wear. The mechanism is designed, however, to carry forces about 5 times their normal value. This is done to provide for the larger forces which may occur during runaway speed and to take care of a hypothetical condition of having the total moments of all the blades concentrated on the mechanism of one blade. Externally, all units have the same general appearance as those employing runners with fixed blades. The generators, governors, shaft couplings, and external mechanism of the turbines are of standard construction.

The five units now in operation have been in continuous service from 6 months to 5 years. No trouble of any consequence has occurred with any of them, and highly satisfactory operating results have been obtained. All units govern very well. The three Kanawha Valley units are of the automatic type remotely controlled, and handle well under that type of operation. As proved by operating experience and as may be seen from a study of the model-blade moment diagram shown in Fig. 8, the blade movement with respect to gate movement is inherently stable. For a given reactive moment and head, there is a rather definite balanced position of the blades for each gate opening. When the gates are moved by the governor, the blades become unbalanced until a corresponding movement of the blades restores the balance. The blades do not over-travel, because such a movement sets up a restoring moment. For slow movement of the gates during normal governing, there is enough friction in the blade mechanism to prevent unnecessary movement of the blades. For large changes in load in either direction, the blade movement follows the gate movement rapidly with very little lag.

Perfect synchronism between gate and blade position, such as to result in the highest possible efficiency at all loads and heads, is not obtained; however, since blade adjustment is automatic for both head and load, the perfection of adjustment is considered adequate.

When any load up to full load is thrown off the unit, the blades close approximately as fast as the gates. This is a desirable condition of operation because, when the gates are closed, the runner tends to screw up in the water and thus to lift the entire rotor. The blades being in their flat or nearly flat position greatly reduce the lifting effect.

Lifting effect on shut-downs is also reduced by the admission of air through the crown plate. It is customary to provide each unit with two rather large air valves of different types. One is of the check type which is forced open by an adjustable cam as the gates close. The valve takes air through a pipe from the outside of the power house and is also used for venting the turbine during normal operation under load at low gate openings. The other air valve is a spring-loaded check, taking air from the turbine pit, and is adjusted to open at about 15 ft. of water vacuum. It opens only when the dropping of load produces a high vacuum under the crown plate. With the air valves in operation and the runner blades reaching their closed position almost simultaneously with the gates, a highly satisfactory shut-down results. Practically no bump can be felt from the top of the turbine or generator when full load is dropped.

The turbine runners and throat rings have proved to be remarkably free of pitting from cavitation. This gratifying experience is attributed to several factors: the models were subjected to extensive cavitation studies; the runner blades are of simple curvature; and the position of the gates and the sectional curvature of the top of the throat ring were selected so that the gates do not project over the curved part of the ring when in their full-load position. This tends to reduce inflow vortexes and to produce a more uniform velocity distribution. Additional studies and experimental work are in progress with a view to further improvements and to the extension of the upper head range. This also includes additional cavitation studies for the improvement of mechanical details.

Among the improvements in mechanical details might be mentioned the arrangement, shown in Figs. 10 and 11, on page 19, for the automatic admission of free air to the draft tube at the runner cap. This is for the purpose of giving smoother operation in cases where the water leaves the runner with a considerable whirl. Such an arrangement is advantageous in preventing vibration in the case of runaway speed or operation at greatly reduced heads and high values of unit speed. Whenever a vortex forms at the runner cone in the centre of the draft tube, a vacuum is produced, even with high tail water, such as to suck in free air through the tubular passages in the piston rod and turbine shaft. These passages terminate with check valves near the upper end of the turbine shaft. The check valves are adjusted so that they will admit air to the draft tube only when a strong vortex occurs at the runner cone.

In conclusion, a summary of the principal features of the new type of hydraulic turbine may be given as follows: (1) Blade-operating mechanism is entirely separate from the governor oil-pressure system and is controlled by the turbine water supply. No extra governor equipment is required and all oil pipes are eliminated. (2) Blade-adjusting mechanism is concentrated in the turbine proper, reducing interdependence of turbine, generator, and governor design. (3) Turbine and generator shaft couplings are of standard construction, the same as for fixed-blade turbines. (4) For normal blade adjustments, forces and moments required to actuate the blades are a minimum, due to the location of the pivot point and the use of roller bearings. (5) Blades open when starting turbine, tending to protect the main thrust bearing. (6) Blades open at runaway speed, appreciably reducing over-speed and cost of generator. (7) Use of heavy grease in hub versus heavy oil. (8) Inherent tendency for blades to adjust themselves to the condition of operation. (9) Blades follow gates rapidly on quick shut-downs, greatly reducing lifting effect and forces on the blades. (10) Provision for automatic suppression of vibration with free air in the case of overspeed.

AMERICAN SOCIETY FOR TESTING MATERIALS.—The sixteenth Edgar Marburg Lecture of the American Society for Testing Materials was delivered by Dr. H. L. Fisher on June 25, during the course of the Society's annual meeting in Chicago. The subject of the lecture was "Natural and Synthetic Rubbers."

WAR-TIME BUILDING SUPPLIES.—The Ministry of Works and Buildings has issued a list of revisions to the second (November, 1940) edition of the Schedule of Requirements of Building Supplies for Government Departments. Copies of the list, which is dated May, 1941, may be obtained from H.M. Stationery Office, York House, Kingsway, London, W.C.2, price 1d. not including postage.

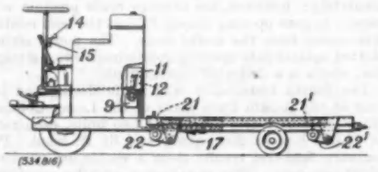
"ENGINEERING" ILLUSTRATED PATENT RECORD.

ABSTRACTS OF SPECIFICATIONS RECENTLY PUBLISHED UNDER THE ACTS OF 1907 TO 1939.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned, the Specification is not illustrated.
Where inventions are communicated from abroad, the Names, etc., of the communicators are given in italics.
Copies of Specifications may be obtained at the Patent Office Sales Branch, 25, Southampton Buildings, Chancery-lane, London, W.C.2, price 1s. each.
The date of the advertisement of the acceptance of a Complete Specification is, in each case, given after the abstract, unless the Patent has been sealed, when the word "Sealed" is appended.
Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any of the grounds mentioned in the Acts.

LIFTING AND HAULING APPLIANCE.

534,816. Stillage Truck. Aero Engines, Limited, of Bristol, and G. E. Halliday, of Bristol. (7 *Figs.*) July 15, 1939.—The invention is a hydraulic raising and lowering system for stillage truck platforms. The truck is of tricycle form, the front wheel being steerable and driven by an internal-combustion engine, which also continuously drives a unidirectional hydraulic pump 9. The engine casing also houses the pump control valve and reservoir 11 for the hydraulic fluid. The pump and the hydraulic fluid reservoir are directly associated, the reservoir, in turn, enclosing the control valve 12. The valve is operated by a Bowden cable controlled by the hand lever 14 on the steering column. An outlet of the control valve is connected with a single-acting jack 17, which is mounted between a fixed cross member of the chassis and a pivot carried by the levers 21. The jack operates through the levers 21 and 22, which are keyed on a cross shaft, each lever 22 being connected to a lug on the platform. At the rear end of the platform are similar levers 21′, 22′, the lever 21′ being coupled to the jack and the front lever 21 by a connecting rod. The reservoir 11 is connected directly to the suction and delivery ports of the pump 9, so that the only external connections necessary are the pipe line connecting the jack to the selector valve. Also, since the control valve 12 is entirely within the reservoir 11 it can be kept immersed and ordinary leakage need have no effect on the operation



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of the valve. The control valve has two spring-loaded ball valves, which are controlled by plungers operated by the control lever 14. A third or relief valve is opened only when the pressure exceeds that required to operate the jack. To lift the platform, the control lever is set in the first notch of a gate 15, in which setting oil from the pump forces the delivery valve off its seat and passes along the pipe line to the jack 17. When the platform reaches its maximum lift, the excess oil is returned to the reservoir through the relief valve. When the control lever 14 is moved to the second notch, one plunger pushes the exhaust valve off its seat so that the oil is idly circulated and returned to the reservoir 11, the pressure being maintained in the jack by spring closure of the delivery valve. There are two control positions of the valve for lowering the platform, one for when the platform is carrying no load and the other for when it is fully loaded. In the former case the hand lever 14 is moved into the third notch of the gate 15, and the plunger lifts the delivery valve off its seat and the pressure in the jack is relieved, the oil passing back through the restricted passage afforded round the valve, which ensures that a lightly loaded platform cannot be lowered with shock. For lowering the platform under a full load, the control lever 14 is moved to the fourth notch, when a shoulder on the plunger enters the passage above the valve seat and still further restricts the oil flow. (*Accepted March* 19, 1941.)

MACHINE TOOLS AND MACHINE-SHOP EQUIPMENT.

530,348. Bending Shaped-Section Strips. The Austin Motor Company, Limited, of Northfield, F. C. Dolby, and S. G. Cramp, of Northfield. (2 *Figs.*) June 22, 1939.—The machine is for use in bending already shaped section strip, such as sheet-metal framing for the inner edges of window apertures of motor cars. The top of the machine forms a table 10 through which projects an arbor carrying a former 28. A nut 29 holds the former firmly in place. A long arm 30 is pivoted on the table top, and integral with it is a mounting plate 32, on which is pivoted a tool carrier 33. A tool slides along the carrier and is composed of a rear portion 37 guided in the carrier 33, a forward portion 38 (Fig. 2) free to rock laterally in relation to the portion 37, a leading block 40 carrying a fixed projection 40a shaped somewhat to the interior contour of the strip and a second block carrying two projections, each of which fits into the strip. The projection 40a effects the bending of the strip while the other projections lie in the strip and prevent it from buckling. On a forward extension 48 of the tool carrier 33 are mounted two rollers 49 which bear against a flange 50 running round the lower edge of the former. In this way the carrier is located in relation to the former and kept approximately

Fig. 1.

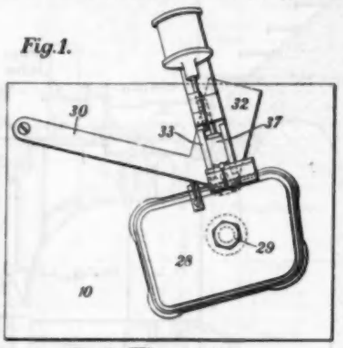
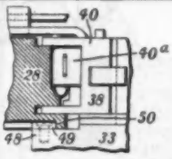


Fig. 2.



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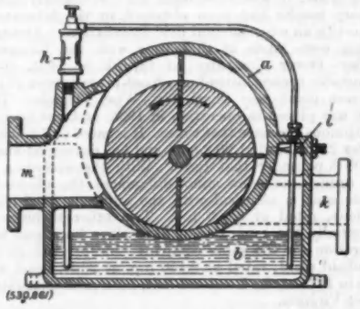
normal to its surface. The tool is forced into contact with the strip on the former by a compressed-air plunger. In operation, the tool is retracted by its plunger and the strip to be bent is clamped to the former 28. The tool is then advanced by the compressed-air plunger into contact with the strip. The motor is then started up so that the former revolves and carries the strip past the tool. The reaction of the outward pressure on the tool carrier 33 is taken by the rollers 49 and the flange 50 on the former. The strip is bent to the shape of the former, its two ends then coming close together. At the end of the bending operation, an automatic trip retracts the tool and stops the motor. (*Accepted December* 10, 1940.)

PUMPS.

530,861. Lubrication of Rotary Compressors. The Hammond Engineering Company, Limited, of Enfield, J. M. Rubury, and W. R. Hammond, of Enfield. (2 *Figs.*) July 3, 1939.—The invention is a lubricating system for rotary compressors or exhausters, which is efficient and reliable without adding moving parts to the machine. The cylindrical casing *a* with a delivery *k* and a suction *m* has a box-like bedplate which forms a reservoir *b* for the lubricating oil. The bearings of the rotor are lubricated through the usual oil channels, but for the lubrication of the blade tips in the casing drops of oil are fed into the suction branch *m* to be entrained by the



(530,861)

air or gas passing through, the rate of feed being adjusted by a sight-feed lubricator A. When the pump is operating as a compressor, the delivery side is opened to the oil reservoir *b* through a small auxiliary port slightly in advance of the delivery port *k*, the flow of air or gas through the auxiliary port being externally controlled by a screw-down needle valve *l*. When the pump is operated as an exhauster, oil is drawn through the sight-feed lubricator A by the reduced pressure in the suction *m*. Delivery of the oil to the bearings is effected by the small delivery pressure, which can be augmented by the admission of air into the suction branch *m* through an automatic snifting valve. (*Accepted December* 23, 1940.)